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High School Water Quality Curriculum for Rural and Urban Areas

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HIGH SCHOOL WATER QUALITY CURRICULUM
FOR RURAL AND URBAN AREAS

by

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A capstone submitted in partial fulfillment of the requirements for the degree of Master
of Arts in Education: Natural Science and Environmental Education

Hamline University

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To all those who have supported my educational journey in life. Countless experiences have brought me to where I am today, shaping my educational and environmental philosophies.

“There’s plenty of water in the universe without life,
but nowhere is there life without water.”
-Sylvia A. Earle

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CHAPTER ONE

INTRODUCTION

Introduction

I have the privilege to teach in a small, rural school district in Minnesota's farm country. Included in my curriculum are two classes that pertain directly to the environment: Wildlife Conservation and Natural Resources Science. Given all of the news in recent years about water quality issues, I have chosen the topic for my Capstone with Hamline University's Natural Science and Environmental Education program to be "integrating solutions to water quality issues in high school natural resources curriculum." Based on that specific topic, my primary research question is "what practices should be taught to students to be sure they are stewards of water quality?" The findings will be used directly in my Natural Resources Science class, and possibly in portions of my Wildlife Conservation class.

Rationale

Many people might wonder why this particular topic should matter to a high school agriculture teacher and his students. The reasons for that are many. First off, the very nature of farming demands a coexistence with the environment, including water quality. After all, agriculture is essentially the application of nature to raise food, fiber, fuel, and building materials for society's benefit. Agriculture needs to take care of water so water can take care of agriculture. Furthermore, being a state with over 10,000 lakes, thousands of miles of shoreline, and thousands of miles of rivers, there's a lot of water to

protect in Minnesota. Factor in rural and urban land uses in Minnesota and it becomes clear that there are major threats to water quality in the state.

The time is now to drive home this issue with students so they can immediately start to make sound decisions on the matters that impact our water quality. Some of the students are involved in activities as teenagers that can impact water quality. Some live or work on farms where there could be more conservation tillage done or other crop fertility strategies could be implemented. Perhaps more awareness of proper manure management could make a difference to a nearby lake. Other students might help fertilize their lawn at home and could use best practices there to reduce runoff during rains into nearby streams.

It's also true that many of the students in today's high school agriculture classes are not directly involved in farming. These students need to learn what the average homeowner can do to help with water quality. They might have a family cabin on a lake where decisions made will impact the health of the water. I would also argue that all students can benefit from learning about precision agricultural technology. Precision agriculture relates to modern technology which allows farmers to "prescribe" nutrients to specific areas of a field where they are needed, and so much more. In fact, the possibility of precision agriculture to transform farming is truly remarkable. Thanks to precision agriculture, we have tractors that can drive themselves in a perfectly straight line, planters that can vary seeding rates within a field, sprayers that minimize overlap, and more. Students who will farm in the future will likely use this technology someday if they don't already, while the non-farm students will benefit by being more "ag-literate" about what is being done by farmers to help the environment.

I hope to find through this Capstone project which specific practices are best to teach to students in my classes and determine which methods are the best methods with which to teach them. Considering the importance of water to recreation in Minnesota, the health of its citizens, its role in agriculture and how our decisions impact entire ecosystems and the water of other states, this topic is paramount to our environmental future.

Context

I developed a passion for agriculture from a young age. My grandfather was a hobby farmer for many years. I can still remember helping stack hay for his cattle with my father and uncle, milking goats with my grandmother, and feeding chickens. My grandparents got out of farming long ago, but that interest carried on with me as I grew older. When I was old enough, I had the opportunity to work on my neighbor's dairy farm. It was a typical small family dairy farm where we milked fifty cows and raised our own steers and heifers. I had watched the farmers make the hay on the field by my house for years and the job was a bit of a dream-come-true for a Wisconsin teen. I got to drive tractors, feed cattle, milk cows, harvest crops, and much more. I learned a lot on the farm and the work-ethic I developed will stick with me for the rest of my life. The hard work of a dairy farmer can really put other work in perspective. When fellow teachers complain about the long days when we have evening parent-teacher conferences, I think back to the twelve-plus hour days I worked on that farm and realize that four hours of evening conferences is not that bad. That time on the farm inspired me to pursue an education and career in agriculture and is a big part of what made me who I am today.

There was a unique factor to that farm that I didn't realize at the time of the farm's location. Like all of the other farms in that part of Wisconsin, we were located within the Lake Superior Watershed. That meant that we needed to be mindful of handling manure and crop fertilizers to minimize runoff into the lake. I am glad we did use smart practices to minimize erosion and runoff as the lake itself is another passion of mine. I had been taught from a young age about its size, its importance, and how it is cleaner now than it once had been. When I was in elementary school, I took a summer school class with some of my friends called "Lake Superior Studies." It was a great class that taught us all about the lake and took us on field trips all around the region. I was very fortunate to have had such great educational experiences. Lake Superior was, and still is, very important to me. I no longer live up there so seeing the lake is no longer an everyday occurrence, but it is still a special place to me when I visit.

In the years since my time on the farm and growing up in northern Wisconsin, I have learned a lot about water quality. The father of one of my best friends was a soil conservationist. I spoke with him a lot over the years about land use and shadowed him for a day to learn about projects he was doing to improve soil and water health. Once in college, water quality was a definite focus of several classes I took at the University of Wisconsin-River Falls. When I student taught, we had a class called "Fresh Water Aquatics" and I learned a lot there as I taught lessons relating to fish and aquatic ecosystems. I am now in my eleventh year of teaching and I have covered water use and quality in various ways over the years in my own classes. Even as a part of my Masters program with Hamline, water quality has come up several times. I even took an elective class through the American Museum of Natural History that was specifically about water.

I have been fortunate to have learned a lot about water and water use and I am also in a unique position as a teacher who covers the topic. I have the opportunity to guide students in the right direction regarding water quality.

I carry my passion for agriculture with me every day. In an effort to keep pace with news in agriculture and technology, I monitor ag-related news regularly. I watch AgDay several times a week, an agronomy show called AgPhD weekly, listen to AgriTalk almost daily, and read several newsletters and magazines. It allows me to know about environmental problems relating to agriculture, what is being done and what can be done. It tells me that there are solutions out there, many people are already doing the right things, and that there is room for improvement. And, as a person who cares about agriculture personally and professionally, I am motivated to stand up for agriculture with my students by being sure they know what can be done to help water quality.

It seems as though the issue of water quality is one that is certainly not going away, as I look at various news stories. We have learned a lot through science about non-point source pollution and it is revealing many sources of water quality issues. It makes sense, really. Point-source pollutants are easier to identify and eventually address since they are the dirty smokestacks and toxic discharge pipes of the world. But non-point source is tougher since it is the yard, field, road, and parking lot runoffs of the world. Many of the news articles are quick to point a finger at practices in production agriculture that are contributing to water problems. Issues relating to soil erosion and fertilizers, such as nitrogen, phosphorus, and potassium, and livestock manure reaching lakes and rivers have been concerns over the years. There have also been worries about crop

production practices that have drained some wetlands and use of tillage practices and crops that allow for exposed soil and potential runoff during heavy rain events.

Meanwhile, other studies, ones that seem to get less attention, do identify issues within towns and urban environments. This can include rain washing pet excrement and lawn clippings into storm sewers and nearby rivers as well as automotive fluids off of parking lots and roads into ditches and waterways. Clearly, both rural and urban parties are guilty to an extent. Are things better than they used to be? In some ways, they are. Some people yearn for the "good old days." But there was a lot more instances of soil loss to erosion and damage to water, less regulation in wetland drainage, and far less efficient use of plant fertilizers back then. Let's not forget about the horrors of The Dust Bowl, arguably the greatest agricultural disaster in American history. Technology and science has brought us a long way and it's a story that today's students should know while they prepare to take things to the next level in the future.

As stated, the good news is that we live in a place and time with remarkable amounts of science and technology that can be dedicated to solving problems. If the farmers, home owners, and landowners of the future make the right decisions, there is no doubt that many of our water quality concerns can be addressed and our entire society will benefit. The technology, science, and equipment happen to be available to be sure manure and fertilizers are applied properly to reduce environmental negatives. It is also true that more can be done to reduce the impact of tillage and soil erosion. For the non-farmers, there are many options to handle runoff from roads and parking lots. Homeowners can do their part to apply lawn fertilizers appropriately and reduce amounts of organic matter that washes into various waterways. Considering the future plans of

some of the students in my classes, I hope to shape some of their attitudes and plans regarding water.

Summary

I am in a unique position as a high school agricultural educator who teaches classes about wildlife and natural resources. I plan on exploring various practices relating to integrating solutions to water quality issues in high school natural resources curriculum. Given the concerns of the general public regarding water quality in Minnesota's rivers and lakes, it's more important than ever to teach about best practices in farming, recreation, home and yard maintenance, and even in managing the urban landscape. The technology does exist to greatly reduce environmental negatives from farming and other areas. The primary research question is "what practices should be taught to students to be sure they are stewards of good water quality?" This Capstone project will explore what land and water use practices will result in water quality improvements and how to best teach them to students.

CHAPTER TWO

LITERATURE REVIEW

Introduction

What are the problems and solutions regarding Minnesota water quality issues and what are the best methods to teach high school students to become stewards of water quality? The problem of water quality in the state of Minnesota and many other areas of the United States is quite significant. While improvements have been made, concerns still exist. Whether the issues are rural in nature or from towns and urban settings, there are possible solutions to reduce water quality problems. There are several viable options to teach these concepts to high school students and make a difference in the future. Regardless of a student's connection to the land and water, today and in the future, steps can be taken to improve water quality for the entire state and country. The major approaches to this subject are going to be broken down in the following ways in this chapter:

1. Overall water quality issues in the state of Minnesota ó This section will delve into the water issues of the day, what has been in the news, and why this is a concern for all citizens of the state, whether rural or urban.
2. Water quality concerns linked to farming in rural Minnesota and potential solutions ó The second topic of this chapter will explore links between farm practices and water issues. There will also be an in-depth look at what can be done to reduce farming's impact on water as considerable innovations are now available to farmers that did not exist years ago.

3. Water quality concerns linked to towns and urban Minnesota and potential solutions ó After reviewing literature on farming's impact on water, there will be a thorough exploration of water quality issues linked to non-farm areas due to development. Wherever there is a road, roof, parking lot, or sidewalk, the natural hydrology of the land has been modified. This means that several considerations should be taken into account to deal with water in such locations.
4. Educational strategies and water education resources ó Finally, after water issues and possible methods of mitigation have been covered, an analysis of teaching strategies that can help address these subjects with high school students will be presented. Additionally, educational resources that are specific to water education will be reviewed.

Overall Water Quality Issues in the State of Minnesota

There is no doubt that there have been improvements to water quality in the United States in recent decades. Rates of erosion and chemical pollution of water have both been significantly reduced. Rivers have no longer been catching fire, like the Cuyahoga River in Ohio did several times (Latson, 2015). Point source pollution, where the source of pollution is obvious, like a main discharge pipe into a river, was a problem for a very long time (Miller, 1991). However, issues like polluting drain pipes from factories into rivers have been largely addressed. The next frontier of water quality in Minnesota and elsewhere in the United States has been nonpoint source pollution. According to Miller (1991), "nonpoint sources are big land areas that discharge pollutants into surface and underground water over a large area" (p. 249). In these instances the pollution source is harder to identify. Water quality issues are often the culmination of

several factors, including runoff from roads, parking lots, yards, fields, and other surfaces. The public and environmental agencies cannot point their finger to one guilty company for their actions resulting in water problems. Instead, the fingers need to be pointed at a large group of land users, including people who drive cars, fertilize their lawns, grow crops, and do several other seemingly benign activities. Citizens should expect water in the Land of 10,000 Lakes to be cared for, safe for recreational purposes, and hopefully not contributing to environmental problems.

Probably the most widely-known water quality issue of our time is the massive hypoxic "dead zone" in the Gulf of Mexico. This is a very large area where excessive nutrient load and other water pollutants lead to very low dissolved oxygen levels in the Gulf of Mexico for long portions of the year. Habitat conditions are very poor, resulting in virtually no aquatic life in the area (Nature Conservancy, 2016). There is no doubt that nutrients from Minnesota and other states in the Mississippi River watershed contribute to this problem. Furthermore, water quality can be a human health issue. When nitrate levels are high enough in water being consumed by people or animals, nitrate poisoning can occur. Studies have shown that nitrate poisoning can lead to issues in being able to process vitamins, impairment of antibodies, and therefore, an increased susceptibility to pathogens (Camp and Donahue, 1994). In order to address and improve water quality in Minnesota, one must learn more about both rural and urban water concerns.

In recent years, it seems as though farming practices linked to water quality concerns have been in the news regularly. Land use in the watersheds of the Minnesota and Mississippi Rivers, as well as many other watersheds in rural Minnesota, is primarily of row crop production. The annual fertilization, tillage, planting, spraying, and

harvesting of crops like corn and soybeans draws scrutiny from many people. Water quality tests revealed many cases of the Minnesota River failing to meet acceptable standards regarding content of dissolved oxygen, phosphorus, nitrogen, turbidity, and fecal coliform levels (Mulla, 2002). There is increasing evidence of connections between farming practices and water quality, as is evidenced by recent news articles, including Kennedy's 2015 Minneapolis Star Tribune article "In Farm Country, Tainted Water is Just the Way it is," where the case of water issues in southwestern Minnesota are outlined. In this particular article, a couple of young farmers defend their farming practices and it is pointed out how important local ag-economies are to rural towns, even at the expense of water quality.

Various other examples can be examined to understand the degree of the water problems in rural Minnesota. The concerns of ag-related water quality issues have even led to some legislation, mainly the Minnesota buffer strip law and Governor Mark Dayton leading Minnesota's first ever Water Summit in 2016.

Similar concerns persist in Iowa, another state where a high percentage of land is used in corn and soybean farming. At the root of the controversy in Iowa are farmers who generally maintain that they are conservation-minded and doing what is right for water and the land. Meanwhile, there are others calling into question just how conservation-minded they are based on water and soil concerns in the state. In the eyes of many, there is a difference between what is being done and what should be done (Comito, Wolseth, and Morton, 2012). As Comito, Wolseth, and Morton point out, these issues are often hard to reconcile when weighing out local rural economies compared to doing what is right for the water and land. Additionally, regulations are often not

enforced effectively and certain programs seeking voluntary enrollment are typically not popular among farmers.

Gaining far less attention in the news, but nonetheless a legitimate concern, are water quality issues relating to towns, roads, parking lots, and other segments of the urban environment. Impervious surfaces are areas where water cannot penetrate, resulting in a high level of runoff. This includes roofs, roads, and parking lots. Storm water landing on these surfaces washes into storm sewers and eventually to streams, rivers, and lakes, almost always without being treated. This rain water takes with it everything from motor oil to leaves to excess lawn fertilizers and dog feces (Quan, Dong, Li, Shen, and Jin, 2014). Each of these things reaches its destination and impacts water quality considerably.

Minnesota citizens should not overlook a couple of other significant water quality issues. The spread of aquatic invasive species threatens the health of aquatic ecosystems across the entire state as well as many aspects of recreation. Another great issue is the lack of wetlands in the state of Minnesota. According to the Minnesota Department of Natural Resources, over half of the original wetlands in the state have been lost due to development and agriculture. According to the Minnesota Department of Natural Resources (2016), additional wetland acres can help filter out water, recharge groundwater, mitigate flooding, and provide wildlife habitat. Thankfully, efforts have increased to restore wetlands, though overall acres of wetlands are not likely to ever rival what they once were.

In summary, there can be little doubt about the fact that water quality in Minnesota and elsewhere has made some significant improvement compared to conditions decades ago, not long after the height of the Industrial Revolution. However, make no mistake that there are still water quality concerns in the state. Both farm and non-farm land use practices have led to water concerns, and there is certainly a need for major improvement. Upcoming segments of this chapter will address water quality issues and solutions for both farm and non-farm areas. This will prove that there are things that nearly every citizen can do to help improve water quality in Minnesota. Methods of teaching this information will also be considered so that students can leave a natural resources class better prepared to be water stewards for our future.

Farmland Water Quality Issues and Solutions

As stated earlier, the primary target of criticism for Minnesota's water quality issues is production agriculture. Much of this is the direct result of an increased use of fertilizer and chemical inputs to achieve higher yields of crops, leading to higher income per acre for the farmer and a greater amount of food being produced overall. According to a 2008 Minnesota Department of Agriculture Timeline, in 1959 the average Minnesota grain farmer was only raising 39 bushels of corn per acre. In 2016, yields that low would be completely unacceptable, as exceeding 200 bushels per acre is now quite common. Several factors have combined for this great increase in a relatively short period of time. Crop genetics, tillage practices, planting and harvesting technologies, drainage of land, and more have all combined to bring about this increase.

Without a doubt, a major factor in this increase is due to the use of fertilizers and various pesticide products (including insecticide, herbicide, and fungicide). Plants

require plant food from the soil to grow to their fullest potential and that is why nutrients are applied to the soil. There have been, and to an extent still are, issues with chemicals and some fertilizers, including nitrogen, potassium and phosphorus running off into waterways and leaching into groundwater. Depending on tillage practices, soil types, and stage in plant development, heavy rain events during the growing season can still lead to erosion and nutrient runoff into waterways.

However, it must be noted that technology and innovations of modern agricultural practices have greatly reduced the negative environmental impact of farming and have potential to accomplish even more. According to Motes (2010), the widespread implementation of conservation tillage and enrollment in the Conservation Reserve Program have led to a reduction of soil erosion in the United States of 1 billion tons per year. When it was first implemented in 1985, it was planned that the Conservation Reserve Program would remove 34 million acres of erodible cropland from crop production, saving an estimated 422 million tons of soil from erosion as well as the cumulative costs associated with that amount of soil loss (Camp and Donahue, 1994). That is a lot of soil that would otherwise be washed or blown off the land, bringing nutrients and chemical residues with it.

There are various options for farmers to choose from when it comes to conservation tillage. Many of these were developed in the years that followed The Dust Bowl, arguably the greatest agricultural disaster in America's history. According to the Minnesota Department of Agriculture's Soil Conservation webpage (2016), conservation tillage is any practice that leaves at least 30% of the previous crop's residue on the surface of the field after planting the next growing season's crop. This includes no-till

and strip-till practices. The positives of conservation tillage consist of increased organic matter content in soils, reduced erosion and runoff, and greater water absorption potential. It should also be noted that reduced passes with tillage equipment can save on fuel and engine emissions from tractors and cut down on soil compaction that can occur with additional passes in a field. Couple this with the fact that modern tractors and harvesters have engines which produce fewer emissions and are more efficient, (Motes, 2010) and it can be stated that farmers are doing their part to improve air quality as well as water and soil quality.

There are several factors that influence the rate of runoff from a field and therefore lead to compromised water quality in agricultural areas. When rain droplets hit bare soil, their impact can be quite significant, even leaving a crater as they loosen soil particles (Ghadiri, 2003). This is why early season rains before crop canopy has been established can be detrimental to soil and water health if conservation tillage measures have not been implemented. Once the crop's leaves are developed enough, they become a primary surface for water droplets to hit, break up, and slow down before they reach the soil, greatly reducing issues of water hitting the ground. Soils with larger particles, primarily of sand, will allow for water infiltration rates much higher than soils consisting of smaller silt and clay particles (Miller, 1991).

Regardless of vegetative cover, once soils are saturated and rainfall exceeds rates of infiltration and absorption, surface erosion and runoff will occur. The level of interconnectedness between soil and water continues when one considers the issue of turbidity. Turbid waters contain some amount of particulate matter suspended in it, often giving it a cloudy appearance. This impacts habitat health for fish and aquatic plants,

recreational opportunities with the water, and can harbor harmful pathogens (USGS, 2015). Some natural levels of turbidity are normal in certain bodies of water as some amount of erosion from streambanks and shoreline is a natural process. However, it cannot be disputed that human actions contribute to it.

One of the developing conservation tillage methods mentioned above is strip tillage. There is great potential with this developing practice. Rather than conducting full-scale tillage, strip till machines till only deep strips in the field, leaving residue on the surface. Often, the equipment is set up to deposit fertilizers in the strips. As was stated by Hagen in Ag Scene (2016), strip tillage reduces passes in a field, reduces soil compaction, and increases nutrient efficiency. This practice can lead to reduced fuel costs and even considerably scaled-back nitrogen fertilizer rates (Gronau, 2016). This system does require the purchase of equipment that many farmers do not have, plus to fully reap the benefits environmentally, there are some precision agricultural practices that need to be employed. Such technologies will be discussed later in this chapter.

It really should be noted that there are other practical methods that can be employed by farmers to result in less erosion and less nutrient and chemical runoff from the land. When hillsides are used in crop production, it is ideal to use contour farming, grass waterways, contour buffer strips, or other such methods (MN Dept. of Ag, 2016). When properly used, a great deal of nutrient runoff and soil erosion is reduced simply because it is not as easy for the water to flow down the hill and carry soil and nutrients with it. Such practices are relatively common in hilly regions, such as the bluffs of southeastern Minnesota and southern Wisconsin.

Conservation methods of farming can go beyond tillage. Farmers who raise livestock also have options to minimize the environmental impact of their operations. Water quality can be compromised by runoff of manure that has been spread on fields, just like other fertilizers spread there. Surface spreading of manure can lead to particular issues when rain events lead to runoff of nitrogen and phosphorus from the soils where manure had been applied. Modern equipment allows for liquid manure to be injected beneath the surface of the soil (Fisher, 2011). Not only does this make agronomic sense, but it is much better for the water within the field's watershed. These practices have been primarily done with hog and cattle manure, though future innovations will surely find a way to utilize poultry litter as well. Many farmers consider and implement several "best management practices," or BMPs, when spreading manure in traditional methods. This includes testing manure to know its nutrient content, testing soils to know where nutrient needs exist, restricting runoff from barnyards and feedlots, spreading manure in ideal locations and in ideal conditions, all done to reduce runoff into nearby waterways (USDA ARS, 2006).

Yet another practice that can mean healthier water in farm country is the use of cover crops. The cover crops main page found on the Sustainable Agriculture Research and Education website (2012) defines cover crops as a crop or plant that "is used primarily to slow erosion, improve soil health, enhance water availability, smother weeds, help control pests and diseases, increase biodiversity and bring a host of other benefits to your farm." Most cover crop usage in Minnesota occurs in wet years when farmers are unable to get their intended crop in the ground in a reasonable timeframe. Rather than leaving the ground bare, exposing it to erosion and putting soil microbes in

an unhealthy environment, many choose to plant a cover crop mix. In many cases, these will keep nutrients in place, reduce runoff concerns, break up soil compaction (which can aid in water infiltration), and possibly even add nutrients if legumes are used.

While cover crops are rarely harvested, their services can lead to improved yields in future crop years. Cover crops are also regularly used after an early season crop is harvested. For example, if winter wheat is harvested in early-to-mid summer, rather than leaving the ground bare, cover crops are often planted.

Of course, there are some possible negatives of cover crop use. Some plants used in cover crop seed mixes feature considerable taproots. A taproot is a plant root system where one main root extends deep into the ground, rather than a broad network of root hairs branching into the soil. The main cover crop plant featuring a taproot is the tillage radish. Tillage radish is a variety of radish that features such a deep root that it can help till the ground, as its name implies. There have been some instances of tillage radish taproots going deep enough that they reach and plug up tile line intended for land drainage (Ag Talk, 2013). Of course, that is a possible testimony to the radish's potential to break up soil compaction, which is a positive effect of the tillage radish. Other possible cons of cover crops relate to additional seed costs, competition between the cover crop and your primary crop (when they are inter-seeded), and possible introduction of new weeds and pests (Curran, Lingenfelter, Garling, and Wagoner, 2016). Generally, cover crops are regarded positively in the agricultural world and it would be ideal to see additional implementation.

What motivation is there for farmers to use any or all of the conservation practices outlined here? First, farmers in the state of Minnesota, similar to farmers in other states, can benefit financially from many conservation programs. If practices are going to be changed and land is going to be taken out of production, government programs can help make up for income that would otherwise be lost. Many of these programs are made available through the Natural Resources Conservation Service division of the United States Department of Agriculture. In fact, the Minnesota Department of Agriculture has a web page with dozens of conservation-related practices farmers can consider (Conservation Funding Guide, 2016).

Government payments to farmers for certain cropping practices have been around since the 1930s. One of the most famous programs is the Conservation Reserve Program, or CRP. According to a USDA news release about CRP (2016), the Conservation Reserve Program has set aside millions of acres of marginal cropland that is otherwise susceptible to erosion and not likely to produce high yields. It has benefited wildlife and recreation considerably, as well as reduced erosion and runoff. Considerable amounts of nutrients like nitrogen and phosphorus would have reached rivers and lakes if it were not for the efforts of the Conservation Reserve Program. Permanent natural vegetation makes a huge difference on these acres, eliminating the risks to water that come from exposed soils.

However, rental payments for acres in CRP are often not high enough to offset potential profits from raising crops on that land when commodity prices reach high enough levels (Babcock, 2007). As a result, many farmers choose to opt-out of CRP in favor of row crop production, even if it's not what is best for soil and water quality. To

address some of the losses of land from CRP, the 2014 Farm Bill included components requiring compliance in several conservation categories to receive various benefits from the USDA (Conservation Compliance, 2014). It should also be noted that some local watershed districts also offer programs that help pay for the cost of installing buffer strips that help filter water and reduce soil erosion (Forum News Service, 2016). Such incentives can make a legitimate difference.

Of course, another motivator to farmers is a desire to do the right thing for the environment, knowing that their livelihood is dependent upon natural systems in the first place. It is largely why farmers and other ag-related professionals formed the Responsible Nutrient Management Foundation (2014). Farmers know it is in their best interest to work together to do the right things and that it does relate to public perception on many fronts. In several instances, farms are spending many thousands of their own dollars to build structures and change practices in an effort to do what is best for water quality (Marcotty and Kennedy, 2015). That is a great concept since Marcotty and Kennedy also point out the costs put upon Minnesota taxpayers for water cleanup, largely as a result of water quality problems linked to farming. According to that article, Star Tribune found that nearly \$125 million was spent to address water contamination in Minnesota.

Still, many farmers are not going to voluntarily build structures to contain manure, implement conservation tillage, or other practices. That brings about laws requiring such things be done. The law that gained the greatest amount of attention in Minnesota is the state's new "buffer strip" law. The legislation calls for an increase from 16.5 feet to 50 feet of permanent vegetation along streams, ditches, and other waterways,

in an effort to filter out sediment, nutrients, and chemicals from water. As one would expect, there was resistance from farmers, farm groups, commodity organizations, and others, leading to much debate over which lands are subject to the law in the first place (Marcotty, 2016). Furthermore, disagreements regarding the Minnesota Department of Natural Resources' role in mapping out and enforcing the law have also surfaced. Still, environmentalists praise the law as a step in the right direction.

Many in production agriculture are opposed to any law that would take many acres out of production without compensation, and are not in favor of a "one size fits all" approach. They feel that 50 feet might be excessive in many places while admitting that it would be inadequate in others. Topography, soil type, land use goals, and much more all play a major role in appropriate uses of buffer strips. Regardless of the size, when done appropriately, buffer strips allow for space to keep sediment, nutrients, and chemicals to be stopped before flowing into a ditch, creek, stream, or lake.

Given the myriad of benefits of conservation tillage and the other motivating factors to participate in conservation programs, why are there still so many acres across Minnesota and other states where full-scale tillage, often done in the fall, is still done so much? Many Minnesota farmers feel that their soil types are such that they hold water to a large extent and would be very slow to dry out in the spring without considerable tillage being done (B. Hefty, personal communication, June 5, 2013). Furthermore, fall tillage exposes soils so that they warm up faster in the spring, resulting in ideal conditions for planting, germination, and emergence, each of which is key to getting a crop off to a healthy start and can lead to higher yields (Davidson, 2014). Also, if fall weather allows, many farmers choose to work the ground at that time since there is no guarantee of

cooperative weather in the spring. It is entirely possible that the fields will dry out just in time for planting, allowing little time for tillage and spring fertilizer applications. Still, it is understood that tillage exposes land to increased risks of soil erosion regardless of the time of year.

Any true analysis of agriculture's potential to improve water quality would fall short if it does not include the potential impact of precision agriculture technology. Thanks to global positioning system applications to farming, nutrients can be applied with considerably greater efficiency. Soil sampling of fields and careful consideration of soil types can be used to create field maps and apply fertilizer in variable rates (International Plant Nutrients Institute, 2011). Additionally, new technologies in equipment allow for individual units on planters and sprayers to be shut off, reducing waste from overlap. Reduced waste of pesticide and nutrient applications to crops all result in less of those substances being released into the environment where they may result in water quality issues. This is also ideal to farmers because all crop inputs, including fuel, pesticides, and fertilizers cost money; if there are ways to use them more efficiently and reduce waste farm profitability can go up.

Modern technology also allows farmers to monitor yields within a field during harvest (Motes, 2010). This makes it possible for farmers and agronomists to track areas within a field where yields were high and there was adequate fertility and areas where the field was lacking. Emerging technology is also an avenue for variable rate planting to maximize crop yield within a field. Basically, this technology will enable farmers to plant a higher or lower seed density in a field, based on soil type, available nutrients, and other conditions (Franzen, 2009). This also can relate to water quality because anytime

farmers can make the most efficient use of a given acre of land, there will be a reduced need for additional land to produce a given amount of food. More marginal cropland will be able to be taken out of production and more conservation practices can be implemented, all resulting in fewer water quality problems.

Possibly the greatest potential of precision agriculture when it comes to conservation practices relate to implementation of strip tillage. As was pointed out previously, this is a reduced tillage practice where narrow strips are tilled while the majority of a crop's residue is left on the soil's surface. Where precision agriculture comes into play is with GPS-guided planting that allows the farmer in the spring to plant the seed in the exact trench where the tillage equipment plowed a strip in the fall. Furthermore, through soil sampling and precision application of fertilizers in the fall, a prescribed amount of nutrients were added to the strips in the fall. Then, preparing for planting in the spring requires minimal fuel usage and causes minimal soil compaction. This all allows the ground to maintain considerable crop residue on its surface, reducing runoff into nearby waterways (Hefty, 2015).

The advantages of these practices are considerable, but they are not cheap. Investments relating to machinery, as well as computers and software to fully utilize precision agriculture, can cost many thousands of dollars. It is hard to quantify when it is justifiable for certain farms as it all depends on the size of the farm, their willingness to learn about the new technology, what equipment they currently use, and so on. Basically, every farm is different, so expecting all farms to invest in the new technology fully and get the greatest benefit to water and other elements of the environment is hard to expect. Depending on the initial costs, commodity prices, and other factors, a farm might be

looking at an investment that will take many years to justify. That being said, farmers should weigh in numbers such as the average annual savings of 12% on fertilizer, seed, and chemicals (Johnson, 2012). Furthermore, the longer technology is on the market, the more affordable and user-friendly it generally becomes.

In conclusion, the major land use of millions of acres of land in Minnesota is row crop production. Farming practices done in the past and today put considerable blame for water quality issues on the shoulders of farmers, much of it justifiable. That being said, there have been many conservation efforts made over the years, with considerable success, to reduce nutrient runoff from farming practices. Meanwhile, modern technology practices and precision agriculture technology allow for great potential to reduce inputs for crops and efficiently produce food on our land. Furthermore, several initiatives are in place to help clean up water in farmland, including mandates regarding buffer strips along waterways. Of course, blame for compromised water quality does go beyond farm practices. Therefore, to explore other players in the water quality game, the chapter will explore information relating to urban and town-related water issues as the next topic.

Urban and Town Water Quality Issues and Solutions

When it comes to water quality, there's no denying the fact that a great deal of nutrients, sediments, and other pollutants flow into rivers and lakes from towns and larger urban environments. These runoff situations especially express themselves during hard rain events when storm water flows unfiltered to nearby streams and ditches, taking whatever it picks up along its way. One of the greatest offenders can be people who over-fertilize lawns or are careless when applying lawn fertilizers. Results of an EPA

study were included in an article on the Washington Post's website, stating that 40-60 percent of the nitrogen applied to lawns ends up in ground and surface waters (Mooney, 2015). That is generally because people are applying too much fertilizer to their lawns. However, lawn fertilizers can also wash away after they have been accidentally allowed to land on sidewalks, streets, and driveways. The next rain simply washes it away. Mooney's article also explains that the situation has gotten bad enough that some states have enacted laws against phosphorus in lawn fertilizers because of its close link to algae blooms in lakes. In a way, the issue of over-fertilizing lawns is an inane one. Mooney mentions results of a survey conducted regarding motivations to fertilize lawns that revealed nearly half of homeowners only fertilize lawns because their neighbor is doing it. Researchers are quick to point out that this issue is not whether or not lawns are fertilized; it's if they are being fertilized excessively. There appears to be a mindset that "if a little is ok, then more is better" when that is simply not the case at all.

Another factor that contributes to the issue of phosphorus loss from lawn fertilizing is soil quality. Throughout most of the Midwest, topsoil which is rich in phosphorus is replaced or buried by poorer subsoil, leading to struggling root systems and the need to supplement nutrients (Bigelow, Tudor, and Nemitz, 2012). In fact, there have been tests done to monitor runoff from lawns on topsoil compared to lawns on subsoil. On test areas where grass was planted over topsoil, there was a much lower rate of runoff compared to grasses planted on subsoil (Cheng, McCoy, and Grewal, 2013). Indeed, individuals involved in developing land for residential and commercial purposes should place higher importance on maintaining topsoil. The responsibility falls to the

professional lawn care providers, home-owners, construction companies, and engineers of cities to do the right thing regarding soils and lawn fertilizers.

Arguably among the greatest challenges to nonpoint source pollution in cities and towns is the issue of impervious surfaces. Impervious surfaces are any place where water is unable to infiltrate into the soil as it naturally would. Considerable movement of people across the planet from rural areas into cities has led to growth and development at a rate exceeding the urban environment's ability to cope with the reduced rates of water infiltration (Tokarczyk, Leitao, Rieckermann, Scindler, and Blaumensaat, 2015).

Imagine many square miles of land where water used to be able to soak into the ground during rain events are now covered by pavement and building roofs. That results in an overload of storm water systems and additional water flow through rivers. Flooding instances are amplified due to the high level of impervious surfaces in many watersheds. Meanwhile, there is also a decrease in the amount of water able to recharge groundwater aquifers. Add to the equation the fact that water reaches storm drains after it has washed over parking lots, rooftops, roads, and sidewalks, picking up dirt, litter, sediment, oil, and other chemicals (Quan, Dong, Li, Shen, and Jin, 2014). These are legitimate threats to the health of aquatic ecosystems and even human health in some cases.

A great deal of research has gone into assessing and addressing urban nonpoint source pollution issues relating to runoff. Unmanned aerial vehicles (often called drones) have been used to assess impervious surfaces and come up with hydrological strategies in Switzerland (Tokarczyk, Leitao, Rieckermann, Scindler, and Blaumensaat, 2015).

Another study dissects an Ohio watershed using GIS data, aerial photos, and field notes to determine the impact of incentives to retrofit some infrastructure with best

management practices to reduce the negatives of storm water (Roy and Shuster, 2009). A study of Xi'an, China explored the role of Low Impact Development (LID) and bio-retention systems to reduce the impact of urban runoff (Quan, Dong, Li, Shen, and Jin, 2014).

Yet another series of experiments was conducted, this time in Australia, to determine the impact of runoff from roofs as it can certainly be every bit as polluted as water washed off of roads (Egodawatta, Miguntanna, and Goonetilleke, 2012). A study of Lake Champlain in the upstate New York-Vermont area explored nutrient runoff into the lake from both the surrounding dairy farms and the boom of housing growth in the area, pointing out that urban storm water contributes 37 percent of the phosphorus reaching the lake (Schueller, 2005). It is clear that there is a lot of concern regarding urban runoff and that science has learned a great deal from the many studies that have been conducted.

An often overlooked contributor to degrading water quality is road salt and runoff from snowmelt. A state such as Minnesota, in a cold climate, can accumulate several feet of snow during a winter, with much of it melting in the spring with warmer temperatures. As is pointed out in the Minnesota Stormwater Manual (2005), it is hard to quantify the impact of snowmelt as some of it soaks into the ground while some runs off the land and moisture levels can vary greatly in different types of snow. What can be quantified is the amount of salt spread on America's roads to melt ice and snow and make travel safer. An estimated 22 million tons of salt, generally in the form of sodium chloride, are spread on roads each winter, which is around 137 pounds per person in the country (Stromberg,

2014). The salt itself is a problem by attracting wildlife to roadsides, drying out plants, and causing damage to vehicles and infrastructure.

The release of chloride into water sources is also a concern. It is possible for chloride concentrations in water to exceed 250 parts per million, reaching the human threshold for detection. Thankfully, at this time, such issues impacting drinking water are not widespread. However, expanding development leads to more roads, more road salt use, and more risk to water contamination. Around 40 lakes, streams, and wetlands in the general Twin Cities metro area test positive for chloride, hurting aquatic ecosystems greatly (Marcotty, 2014).

Unfortunately, it can be hard to convince some drivers and pedestrians that excessive salt used on roads and sidewalks is causing legitimate water quality problems in Minnesota. One option to mitigate the issues associated with sodium-chloride is to use a salt-brine solution on roads. Parts of Wisconsin, as well as other areas of the country, are utilizing a brine solution available from a nearby cheese plant on their roads to melt snow and ice. It does a good job, especially since it has a much lower freezing-point than other salt mixes. Plus, for at least Polk County in western Wisconsin, it makes economic sense as the cheese factory does not need to pay to have the waste-product brine hauled away (Chappell, 2014).

Other alternatives do exist as well. Some municipalities are trying beet juice mixed with salt brine on roads. Whatever the case, if the amount used is reduced, it can make a big difference. Some areas are even working on training their snowplow drivers to use salt in a conservative manner while citizens are encouraged to plant shrubs that

will serve as snow fences. An average of 225,000 tons of salt are used each winter on Minnesota roads, so anything that can be done to reduce that number should be considered. Interestingly, there is one company in Idaho working on a solar highway technology that would keep roadways warm enough from the sun's energy to melt snow and ice (Copeland, 2013). Despite these efforts, due to the effectiveness, affordability, and availability of salt, it is unlikely to be fully replaced anytime soon.

What are some of the solutions to urban runoff issues? Several options have been developed over the years to reduce the impact of impervious surfaces in the developed environment. One possible option is to retrofit existing paved roads with permeable pavement strips on the shoulders, allowing water to soak into the ground after running off of the roadway itself (Kayhanian, 2012). A positive of this idea is that it would not necessarily require the replacement of existing roads, only an addition to the existing shoulders of the roads. The Minnesota Landscape Arboretum in Chaska, MN has an informative parking lot to show how different practices can bring a lot from nearly 100% runoff to nearly 0% utilizing porous pavers and vegetation (MN Stormwater Manual, 2008). It does a great job of demonstrating to visitors what can be done to reduce runoff from a parking lot.

Also gaining popularity is the installation of rain gardens. Rain gardens are low areas constructed to allow rain water to slowly soak into the soil, which is typically populated by native plants (Minneapolis Public Works, 2015). Rain gardens are ideally constructed near areas of impervious surfaces, like parking lots, sidewalks, and rooftops. A great watershed improvement project was conducted at Maplewood Mall in Maplewood, MN. Several rain garden areas were constructed to capture and filter water,

allowing it to soak into the ground rather than flow away. It is estimated that the project now allows for the infiltration of 20 million gallons of storm water runoff annually, reducing phosphorus by 60% and sediment by 90% (Ramsey-Washington Metro Watershed District, 2013). An interactive and educational display is now up in the mall to help educate visitors of their efforts. Furthermore, there is now an increased number of trees in the mall's parking lot, providing the added service of shade where there would otherwise be very little relief from the sun. It is also true that, in many cases, rain gardens are visually pleasing to the public, attract birds and pollinating insects, and can reduce the heat island effect of urban areas.

Another concept that can reduce urban heat is green roofs. While they are still not common in Minnesota, a great example of one can be observed at the University of Minnesota Landscape Arboretum in Chaska, MN. Essentially, a green roof features a waterproofing barrier of some kind, upon which there is soil, stabilizing material, and plants. For the most part, rather than flowing to the ground via gutters and downspouts, water is captured and used on the roof. The plants on the roof can help purify air and water, all while reducing runoff to the ground from the roof (Thompson, 2010). Time will tell if this is a practical option for Minnesota climates, though the proper selections of native plants and ideal construction techniques should prepare a green roof for the state's weather conditions.

In a roundabout way, Target Field, home of the Minnesota Twins, is its own large rain garden. The stadium gained Leadership in Energy and Environmental Design (LEED) certification and has a state-of-the-art system in place to capture, treat, and reuse rain water. The team has worked with Pentair to develop the system, which uses

rainwater collected from a seven acre area for irrigation and washing of parts of the stadium, saving around 2 million gallons of water per year (Pentair, 2016). Smaller residential versions are available to any citizens willing to set up rain barrels. Essentially, they are barrels mounted near downspouts to capture rain water coming off of a building's roof. It is not a new concept as it was done thousands of years ago, but it is gaining more and more popularity as municipal water supplies become stressed and water prices rise (LaLiberte, 2016). The water can be used to water a person's garden as well as other non-potable water uses. Couple this with other practices that help harvest rain, such as rain gardens, green roofs, and porous concrete, and the amount of water sent flowing downstream with contaminants can be greatly reduced (MN Landscape Arboretum, 2016).

Another strategy to slow storm water flow to waterways from impervious surfaces is to construct infiltration or bio-retention basins/holding pond areas. Essentially, these are lower areas which mimic the properties of wetlands by keeping water in place, allowing it to soak into the soil, filtering pollutants, and reducing the water load reaching nearby waterways (MPCA, 2014). Such structures are becoming common near new construction zones, whether next to a parking lot or near highway on-off ramps. While it is true that constructing these features can be expensive, it is also true that there are significant costs associated with water contamination and flooding.

In summation, development has certainly led to contributions to water pollution. Towns, suburbs, and big cities all feature considerable impervious surfaces. These include roads, roofs, sidewalks, and parking lots, all where water washes away and cannot soak into the ground. This excessive flow of water impacts nearby waterways as

well as areas downstream. Many practices carried out in towns can lead to water quality compromises. Excessive lawn fertilizers, oil from dripping engines, road salt, and even animal feces washing with stormwater can cause problems. Fortunately, there are solutions to these issues. These ideas include green roofs, rain gardens, and infiltration areas. Now that the topics of farm and non-farm water quality issues and their possible solutions have been reviewed, methods with which to teach these concepts, as well as water-specific educational resources, should be considered. This exploration will give insight regarding ways to effectively educate high school students on these topics.

Environmental Teaching Methods

Dynamic teaching of any kind involves multiple strategies, differentiation, and adequate student engagement to ensure student comprehension. A topic as important and relatable as water quality involves all people to some extent given that all humans depend on water to survive and thrive day-to-day. Several teaching options exist to cover nearly any given topic with high school students. Likewise, there are many resources that relate directly to the teaching of water quality. This section will connect the water quality concepts already explored to best practices regarding teaching high school students in the 21st century.

A compelling argument can be made in favor of hands-on learning activities as an essential component to teaching. In a 2013 article, the Resource Area for Teaching, or RAFT, argues that the US suffers from an engagement gap, not an achievement gap. How can the engagement gap be solved? The article argues that hands-on learning helps with critical thinking skill development, builds communication and language skills, assists with focus, fosters teamwork skills, can aid disadvantaged students, and possibly

most important is that it can make learning fun. RAFT also supports its claim with some solid statistics in favor of hands-on learning. It was found that 99% of responding teachers felt students had a higher level of engagement and information retention after hands-on learning experiences were utilized (RAFT, 2013).

An additional article supporting experiential learning even draws upon a quote from Aristotle that says “for the things we have to learn before we can do them, we learn by doing them” and argues that hands-on learning is vital with today’s shorter attention spans, where lecturing alone will often fall short (Jayaraman, 2014). A survey was conducted of over 1,600 California students to assess the impact of hands-on learning in the sciences, particularly relating to science projects and experiments. Students were asked to give feedback upon their learning experiences from science projects in school. Feedback overwhelmingly supported student growth and progress thanks to hands-on learning experiences, helping students develop valuable skills for life and careers in the 21st century (Robinson and Black, 2013).

Further evidence for hands-on experiments in science classes is supported by the American Chemical Society. While they do understand and support computer-simulated science experiments, their website clearly articulates that the American Chemical Society feels there is no substitute for solid hands-on learning activities in which materials and equipment are properly and safely integrated (2016).

Without a doubt, there is considerable support for hands-on learning experiences, no matter the age of the students. Of course, in most cases, hands-on learning is the

application of what is discussed in lecture sessions as that will typically set the foundation for the application of the concepts.

A strong argument can also be made for the value of field trips as educational experiences. An in-depth study was done to determine the value of students going on educational touring field trips to museums. Results found that students learned a lot during the trips, including the importance of critical thinking, and those students particularly from rural and impoverished school districts benefited the most from the trips (Greene, Kisida, and Bowen, 2014).

Research by the Center for Advancement of Informal Science Education also supports the many positives of field trips as learning experiences (2015). They found that field trips helped students to step-up interest and engagement no matter their prior interest in the topic. It was also discovered that students would regard a topic more positively after a field trip, and that field trip experiences stuck in student memories for a long time. Their studies did find that adequate preparation was necessary to be sure students would truly benefit to the highest degree possible from a field trip (Center for the Advancement of Informal Science Education, 2015).

Newcomb, McCracken, and Warmbrod (1993) also wrote that field trips are valuable, real-life experiences and can do a great deal for both teacher and student to provide a change from the day-to-day routine. Sometimes, changing things up and making it a different, stimulating, and realistic experience is a healthy thing for everyone involved.

Indeed, if proper planning and follow-through is conducted, field trips can be great educational experiences. Unfortunately, field trips are often the victims of school budget cuts and the number of them conducted has been steadily on the decline, even though their value is well-supported. Also, there is the perception that field trips are not legitimate educational experiences and that they are just for fun, entertainment, and rewards for good behavior.

A third educational strategy worthy of further exploration is that of guest speakers. In many situations, it is a meaningful venture for a teacher to bring in an expert and professional in a given field to impart experiences and knowledge to students. The key to a successful guest speaker session is to be sure the speaker and the class are adequately prepared and that the content covered fits in appropriately to the class objectives for the lesson (Lang, 2008). A teacher must be sure to avoid inserting a guest speaker just for the fun of it or as filler when the teacher wants a break. It should go without saying that such practices should be avoided. Guest speakers, sometimes referred to as "resource people," can be utilized for a multiple situations. First, no matter how well-versed a teacher is on their subject area, it is impossible to be an expert on all topics. Therefore, working with a legitimate expert on a given topic is a wise teaching decision. Additionally, guest speakers can serve to bolster content covered in class, adding validity to the curriculum (Newcomb, McCracken, and Warmbrod, 1993).

In the spirit of this topic, a thorough exploration of resources that are specific to water-related education shall be conducted. A good way to introduce students into the topic of water quality is to be sure students understand what watersheds are and how that impacts water quality. Explanations along with links to educational resources for

classrooms are made available from the Metro Watershed Partners (2007). Another great resource is The Water Project's "Water-related Education Materials for High School" website, with many links to valuable educational resources and lesson plans for students in grades 9-12, including hands-on activities (2016). The Water Project is a 501(C)(3) non-profit organization dedicated to being sure people all over the world, particularly in sub-Saharan Africa, have access to clean water.

Even the EPA is doing its part to provide educational resources to teachers about water quality. Intended for grades eight through twelve, the EPA has a lesson plan available where students can build their own watershed. The plan is complete with background information, a materials list, the procedure and follow-up questions (2016). It is a pretty interesting lesson plan, complete with various ideas to simulate water that is polluted from various parts of its watershed.

Out east, the Massachusetts Water Resources Authority has an entire "Water Quality Testing Manual" that is set up for middle and high school students to be able to do data collections in the field, analysis in labs, and more (2008). The chapters of the manual provide an in-depth amount of information regarding selecting locations to collect samples, how to do so properly, examining the area, working within groups on the projects, getting results on a myriad of water quality criteria and reaching conclusions. The manual is also complete with safety information and materials lists and is a great fit for any class interested in testing water samples.

The Purdue University Extension service also has a complete lesson plan for a board game based on watersheds (Kapitan, Lyttle, Williams, 2013). It is complete with

directions, scenarios, player roles, and a detailed game board. It relates it all very well to real watershed situations.

Most other educational resources about water quality are intended for adult learners. For example, the University of Minnesota Extension Service has a Stormwater Education Program (2016) which puts on programs and has resources available specifically for those in charge of municipalities, contractors, developers, and other such professionals. This resource includes videos and details of training programs. This is an important place for adults to be able to go to learn about this topic. If people in charge of changing the landscape don't realize the consequences of certain actions, it will be hard for them to plan appropriately, and compromises in water quality impact us all.

Also relating to adult learners is a study of areas in the North-Central portion of the United States, where grain production has led to water quality issues (Camara, Martin, Kwaw-Mensah, 2009). Even though the focus of this particular study was on agricultural extension educators and not on those who teach high school students, it is likely the closest-relating research to the subject of this capstone project. It focuses on the Upper Midwest, water quality issues from agricultural land, and how well the messages are reaching those who need to learn about the impact of their actions on the land and water. Conclusions from their research found that more work needs to be done to engage audiences on this topic and that more resources should be dedicated to the cause. Additionally, it was found that activity-based educational programs work best to reach desired levels of comprehension. Furthermore, there needs to be additional training opportunities provided to extension educators, and then relayed to farmers, agricultural professionals, and citizens in general.

Yet another article to consider is “Integrating Extension, Teaching, and Research for Stormwater Management Education,” by Shelton, Rodie, Feehan, Franti, Pekarek, and Holm (2015). As the title states, it’s about several stakeholders teaming up to bolster educational opportunities regarding stormwater, including the concepts of low impact development, green spaces, rain gardens, and more. The results led to several new lectures being added to courses on horticulture, landscaping, and architecture at the University of Nebraska-Lincoln. The plan also worked on developing educational opportunities for learners of all ages through the Nebraska Extension service, including reaching youth in 4-H and older audiences through workshops and tours. It does a great job of showing the value of collaboration by various professionals to meet a need as important as stormwater management education.

In closing, there are many strategies that can be employed to teach students about water quality in a natural resources class. Whenever possible, taking a lesson beyond traditional lecture and discussion practices is ideal. Among the many directions to consider are field trips, bringing in guest speakers, and being sure that as much hands-on learning takes place as possible. These practices are proven to be memorable and beneficial ways of teaching, engaging students in the lessons of the water quality unit. It is also true that there are many resources relating specifically to teaching water quality to students that can be consulted for guidance.

Rationale

The question presented in this capstone is, “what are the problems and solutions regarding Minnesota water quality issues and what are the best methods to teach high school students to become stewards of water quality?” This chapter dissected many

issues and potential solutions. Some of these solutions are new and innovative while others are basic and have been around, to some extent, for a long time. There is no doubt that a lot of effort has been invested in determining the degree of our water quality problems in Minnesota and elsewhere. Now the time has come for every citizen, whether urban, suburban, or rural, whether on a farm or not on a farm, to step up and do the right thing. It is not always easy, though. Costs and general attitudes can certainly get in the way of progress. If anything, this is further support for the need to improve water quality education in high schools. And, there is certainly no better place to implement such curriculum than in a natural resources class. Along with sun, air, and soil, all players in a given ecosystem, including humans, depend on water for survival. An engaging and substantial curriculum for high school students, who are the adults of tomorrow, needs to be integrated now more than ever.

Chapter Summary

This literature review explored many of the available resources relating to water quality in Minnesota and the Upper Midwest. Areas of concern, causes, and solutions, relating to both rural and urban settings were included. Additionally, solid teaching strategies and water education resources were reviewed. This is a very thorough way to consider what has already been written about the question of how to best teach high school natural resources students about water quality. Clearly, a lot of work has been done by researchers, governmental agencies, journalists, professors, educators, and other writers. This information shall be considered moving forward when developing curriculum in future portions of this capstone project.

Moving forward, Chapter Three will explore the methods employed in this research and the corresponding curriculum development. Included with the curriculum development will be the subject matter relating to water quality and practices to mitigate issues as well as specific teaching strategies to teach the unit of study. There will also be a breakdown of the research methods utilized and an explanation of the methodology considered in developing the curriculum. Information on the main stakeholders of this project will be explored, including the setting, age of students, and role of other participants.

CHAPTER THREE

METHODS

Introduction

What are the problems and solutions regarding Minnesota water quality issues and what are the best methods to teach high school students to become stewards of water quality? Chapter One provided an introduction and explored the connections and necessity for this topic to be researched. Meanwhile, Chapter Two comprehensively reviewed research and literature regarding the topics relating to this question. Now, in this chapter, the methods that apply to this Capstone and the development of the proposed curriculum are clearly laid out. In the end, this Capstone states a strong case for the need for additional water quality education and provides educational resources for students in the 21st century. Like a news reporter would approach an important news story, this methods chapter explains the specific components answering the òwho, where, what, when, why, and howö of this water quality curriculum Capstone project.

What is the Setting?

Given the nature of water as a resource, one could argue that everyone on the planet could and should be considered to have a role in this project. A basic understanding of the water cycle proves that the water used for drinking today was once in the ground, once in a cloud, at one time falling to the ground as rain or snow, or once floating around us as vapor on a humid day. Ensuring that water is clean and dependable for use is something that should matter to all people. Knowing the importance of quality water really puts the relevance of the topic in place.

Specifically, this project's curriculum development is targeted to high school students in grades nine through twelve who elect to enroll in a natural resources science class. Typical class sizes for this course are around twenty students. Primary participants are students in a rural school district that is not far from the Minneapolis-St. Paul metro area. These students bring different perspectives to the table. While there was a time when the majority of students in this class would be farm kids, that is no longer the case - something that has changed significantly in recent years. The general trend of fewer farmers and larger farms (therefore fewer students who live on farms) certainly does apply here. Still, several students are directly involved in production agriculture, either on their family farm or through working a part-time job on a farm. Others live in small towns or in the country without any direct connection to agriculture. Regardless of the student's situation, there are many potential connections they can glean from this curriculum's integration. Furthermore, many elements of this curriculum are easily adaptable to a larger, more suburban or urban school setting. This versatility will prove the value of the curriculum developed in this project.

Of course, the people involved do go beyond the students. Qualified teaching personnel are necessary to conduct the lessons. A solid educational and experience background relating to the water quality topics included should be expected. The teacher does not need to be an absolute expert in farming, lawn care, urban development, or runoff. However, an understanding of watersheds and water quality issues should be necessary, along with willingness to research and learn about specific concepts. Given this criteria and my education and experience relating to the content, I feel I am a solid fit for the curriculum tied to this Capstone project. Beyond the educator will be the resource

people involved in the guest speaker and field trip components of the curriculum. Given the prominence of this topic in the news and the attention that it has drawn overall from the public, accessing these experts and working with them is not likely to be a challenge.

What was the Curriculum Development Plan?

The ðwhatö component of this curriculum development plan is the heart of this Capstone project. Several educational strategies are put to use in the development and teaching of this curriculum. At the very root of the development of any curriculum should be reflection. Teachers and other curriculum developers should take the time to reflect on previous educational experiences and determine which strategies worked and which did not. Reflection can give insight to which methods were more effective which were not. All teachers should reflect back on most lessons and units of study to determine effectiveness. Were educational objectives met? How valuable was the teaching? Did students comprehend the vital content of the information taught? It is through this self- reflection that teachers can actively improve methods used in teaching and be sure strategies are successful (Sanders, 2014).

Research, along with reflection on prior experiences in education, reveal which specific areas of content are most important to include in the curriculum. My curriculum development process is one that I have developed over the years and is very similar to the standard embraced by most of the educational community. Consideration of the subject and the relevance of it, the needs of the learners, the teaching strategies to implement, intended outcomes, and assessment are all factors to ponder when developing new or refining existing curriculum (CSDE, 2006). For this particular subject, I asked myself about what I have taught over the years relating to water quality and how I went about

teaching it. I also took the time to research the specific areas that are arguably most important to integrate into the curriculum. Many learners do not know what can and should be done to improve water quality. Furthermore, the “blame game” ends up being played between various stakeholders when virtually everyone has a role and responsibility. Each of these factors will be weighed when developing a rigorous and engaging unit of curriculum to meet these needs.

When will Implementation Happen?

Answering the question as to when this will be done is a relatively open-ended question. The nature of elective agriculture classes in a rural school district lends itself to a certainly level of uncertainty for when a class will be conducted. Each spring, based on student interest during the registration process, class schedules are put together for the next school year. Different from most required classes, where there is a guaranteed number of sections taught each year, elective classes can change from one year to the next. Strong student interest can mean some classes are on the schedule each semester or at least one semester per year. In other cases, a class might only gain enough student numbers to put it on the schedule every other year. In this case, my Natural Resources Science class has gained necessary student interest and is on the schedule for one semester during the 2016-2017 school year. Therefore, development of this curriculum took place during the fall of 2016 with planned integration in a term of classes to soon follow. That being stated, this curriculum was intended to feature flexibility for easy adaptability to a variety of situations. Ideally, this curriculum can be used by teachers in many districts for high school students for years to come. Therefore, answering the

question of when this curriculum will be used is to say that it will be ideally implemented whenever a natural resources or environmental class calls for it.

Context and General Plan Outline

Like most high school classes, my Natural Resources Science class follows a general unit-by-unit progression. Within each unit, key concepts are taught in a variety of ways. Much information is delivered in traditional lecture and discussion format, with application of said information in assignments, projects, and hands-on labs. At the end of the unit, content is reviewed and a unit test is given. This particular unit, which focuses on water quality, would follow a general water unit in the class. That unit will introduce water as a vital resource for all living things on earth. It includes lessons on the water cycle, general information on how water is used, and why water is so vital. It also compares fresh water to salt water. This would set the foundation for the unit on water quality, for which the curriculum being developed in this project will be implemented. It should be noted that prior to the water unit, the Natural Resources class will have been taught a unit on soils. The soils unit will include characteristics of soil, degradation and erosion, the importance of soil, development of it, and more. Air quality will be the unit of study that follows the water quality unit in the course's progression.

The following is the general outline of the water quality unit I have created which addresses the curriculum development question of this Capstone project:

1. Introduction to water quality
 - a. Why water quality is a concern in Minnesota and other places
 - b. Water quality issues in the news

- c. Threats to health based on low water quality

2. What is a watershed?

- a. Runoff: Role of farming, towns, cities, and roads relating to water quality
- b. Perform water quality testing labs on collected samples of soil and water sources to determine levels of nitrogen, phosphorus, and potassium, as well as dissolved oxygen levels of water

3. Farm-related water quality concerns

- a. Role of fertilizers in farming
 - i. Review soil testing information from earlier unit of study in class
 - ii. How are fertilizers, manure, and other inputs applied to fields?
- b. Conservation and precision farming practices
 - i. Cover possible methods of reducing runoff from fields
 - ii. Introduce technology available to lead to cleaner water in farm country
 - iii. Visit a farm on a field trip to see technology and conservation put to use
 - iv. What can be done by current and future farmers?

4. Non-farm water quality concerns

- a. Runoff from yards and impervious surfaces
 - i. Sources of non-farm pollutants
 - ii. Demonstrations showing impact of impact of impervious surfaces
 - iii. Solutions to non-farm water quality concerns
 - iv. Guest speaker to demonstrate and discuss water quality solutions

1. Porous concrete
2. Green roofs
3. Rain gardens
5. Review of water quality unit content by use of an interactive review game
6. Conclusion with unit test

Conclusion

In summary, this water quality curriculum for high school students in a rural school setting assures that the next generation of citizens will be stewards of water quality, regardless of the ways in which they impact land use in life. The curriculum is relevant, engaging, and hands-on. It is also easily adapted to schools and student populations in a variety of settings. These methods are applied in Chapter Four where results of the curriculum development work are shown in the actual lesson plans that have been developed.

CHAPTER FOUR

RESULTS

Introduction

This chapter contains the completed curriculum that I developed relating to water quality issues, including lesson plans, assessments, and connections to standards.

Specific assignments, a quiz, and a test can be found in the appendix. This curriculum is intended to be used in a high school agricultural class focusing on natural resources. The setting is a class in a rural area that is not too far from a large metropolitan area. Class lengths are fifty minutes and this unit plan contains ten lessons, complete with a test on the last day. It should be noted that relatively little adaptation would be necessary to allow this curriculum to be used in other science courses, with different ages of students, and in different settings.

Given that this unit is focusing on water quality, the ideal progression of topics in the natural resources class would be to start with a unit on soils. The soils unit will provide an important foundation that will be connected to future units of study in the class. Following the soils unit should be a short unit introducing water, consisting of lessons on water characteristics and the water cycle. That introductory water unit will work well to set the stage for the unit specifically about water quality, which is the subject of the unit developed in this Capstone.

Some additional planning in advance of this lesson is necessary. It includes a field trip to a farm and hosting a guest speaker, plus hands-on learning activities. Be sure to arrange for transportation in advance. To fully utilize the field trip, be sure the

cooperating farmer has the necessary equipment and field plots prepared. The guest speaker should be someone well-versed in water issues and solutions. Be sure the hands-on lab activity materials are ready for use with the students. The ideal timeframe is early fall, though adaptations could allow it to work during other times of the year. Follow-up should include sending thank you letters to the guest speaker and the farmer that hosts the field trip. A nice touch is to have the class sign the thank you before mailing it.

Agricultural Education Standards Covered in this Unit

There are many standards within the National Agriculture, Food, and Natural Resources (AFNR) Standards that are covered by the lessons of this unit. They come from multiple categories of AFNR standards as have been set by the National Council for Agricultural Education (2009). The following list includes those standards and performance indicators that are addressed by this natural resources unit of study:

ESS.01.01.02.a. 6 Identify basic laboratory equipment and environmental monitoring instruments and explain their uses.

ESS.03.02.03.c. 6 Conduct tests of soil to determine its use for environmental service systems.

ESS.03.03.01.c 6 Research and debate one or more current environmental issues associated with the supplies of groundwater and surface water.

ESS.03.03.02.b. 6 Describe interactions between groundwater and surface water.

ESS.03.03.04.a 6 Identify environmental hazards associated with groundwater supplies.

ESS.03.03.04.b ó Describe precautions taken to prevent/reduce contamination of groundwater supplies.

ESS.03.04.01.a. ó Describe the functions of wetlands and differentiate types of wetlands.

ESS.03.04.03.a. ó Explain the importance of wetland management, creation, enhancement and restoration programs.

ESS.04.01.01.a. ó Identify types of pollution and distinguish between point source and nonpoint source pollution.

ESS.04.01.02.a. ó Describe ways in which pollution can be managed and prevented.

NRS.02.06.02.a. ó Describe properties of watersheds and identify the boundaries of local watersheds.

NRS.02.06.02.b. ó Relate the function of watersheds to natural resources.

NRS.02.06.04.a. ó Define riparian zones and riparian buffers, and explain their functions.

NRS.02.06.08.a. ó Describe sources of pollution and delineate between point and nonpoint source pollution.

PS.02.03.03.b. ó Determine the nutrient content of soil using appropriate laboratory procedures and prescribe fertilization based on results.

Lesson One – Introduction to Water Quality

Objectives ó Students will be able to

- Understand basic potential issues and perceived issues with water from various sources.
- Grasp why clean water is very important to society.
- Comprehend some of the current water issues in Minnesota.

Materials and Supplies Needed:

- Cups or glasses
- Good drinking water
- Computer lab with internet access

Interest approach: (five minutes)

Pour several glasses of water in front of the class and give them to student volunteers in class. Tell them that they can consider drinking the water, but they should know that the water may have come from a variety of sources. Explain that the water was collected from a nearby creek, a nearby lake, the drinking fountain in the hallway, from the Mississippi River, and from a country home's private well. Given that information, ask the class to raise their hand if they would still drink what is in front of them, not knowing what water came from which source. It's likely that very few hands would go up. Why is that? Strike up a conversation about water quality and why the students feel the way they do. It would likely go something like this:

"I know that lake is gross this time of the year."

"The water in that creek is pretty brown sometimes. I don't want to drink that."

"You never know, there could be something in that well out in the country."

That conversation would really be telling about the notions that students have about water sources and give an idea of where the instructor is starting from with this unit of study.

Explain how the class will be starting a unit on water quality, particularly as it relates to local issues in Minnesota. Then, invite the class to drink their water samples as the truth is that it was all collected from the hallway drinking fountain.

Discussion: (ten minutes)

Next, lead the class in a conversation about the importance of water quality. Good water matters to natural systems, crops, human residential and industrial water uses, wildlife and livestock, and other parts of the Minnesota ecosystems. Clean water is a vital component to life and society as well. To investigate the topic further, split the class into two groups and prepare them to do some research in the school's computer lab. The first group is going to be expected to research water quality issues in the news and the second group is responsible for finding information about consequences of poor water quality and why it is a concern.

Investigation: (thirty minutes)

Take the class to the computer lab and allow them to explore online resources for the topics at hand. This will take the class towards the end of the period. Circulate around the lab and assist students as needed. Give suggestions for their research and encourage their exploration of the resources available.

Conclusion: (five minutes)

As the hour winds down, tell the class that they'll need to bring their findings to class with them the next day. To conclude the hour, ask for one particular interesting finding from each of the groups. They will share their information as time runs out and it will serve as a preview for the start of class on day two.

Lesson Two – Water Quality in the News

Objectives ó Students will be able toí

- See how water is used day-to-day by humans.
- Consider implications of direct and indirect water usage.
- Understand the issues relating to water quality based on news articles.
- Discern legitimate news articles from research on a scientific topic.
- Share main points of a scientific article with a group.

Materials Needed:

- News articles from the internet relating to water quality
- Data on water usage, as found in Appendix A

Interest approach: (eight minutes)

Ask the class "how do you use water each day?" List the responses shared by students on the board. You'll see all sorts of answers, such as showers, personal hydration, flushing the toilet, washing dishes, and so on. Be sure to point out the indirect uses, such as irrigation of crops consumed, water consumed by animals we eat, and more. This will help students see the need for clean water in their lives. It is an issue that impacts everyone. To further the point about the need for clean freshwater, have students guess

how many gallons of water are necessary to do various tasks. Compare the findings to the table of data on water used for various practices, which found in Appendix A.

Emphasize the fact that each of these practices requires freshwater, not salt water. Plus, it's important to understand the fact that irrigation leads to many foods we consume, but it is a major consumer of freshwater in the United States.

Then reinforce the concept by reminding the class just how little of the water on Earth is available fresh water. With over 96% of the water on Earth being saltwater and only around 1% is available freshwater for human uses. The need for water conservation is very apparent.

End the introduction by encouraging all of the students to consider what they can do to conserve water.

Discussion: (thirty-two minutes)

Have the class share what they found when they researched online about water quality issues in the news and what can happen when water quality is compromised. Topics relating to the impact of road salt, lawn fertilizer runoff, cropland runoff, erosion, and much more will surely dominate the discussion. Then, issues of human health, animal health, and overall ecosystem degradation will arise relating to consequences. Be sure to connect this discussion back to the interest approach from yesterday with the cups of water. Perhaps some of the students were correct to be hesitant about drinking the water when they did not know the source at the time. Students who live in the country on farms might get defensive about their practices. Others who live in town might get defensive about care for their property at home as well. Some debate on the issues can be allowed,

though be sure to stay neutral and emphasize that there is no need to start playing the blame game in society. Everyone is capable of being part of the cause and solution to these issues.

Wrap-Up and Preview to Upcoming Classes: (ten minutes)

Reflect on the findings of the various articles with the class. Point out positive signs of progress to go along with the issues brought up in class. Explain that in the coming days, factors relating to watersheds, cropland practices, and residential water impacts will be explored. Technology that can help address water quality issues will be highlighted, and in the end, each student will walk away knowing how they can positively impact water quality in their lives both now and in the future.

Lesson three – What is a Watershed?

Objectives ó Students will be able to

- Explain the differences between point and non-point source pollution.
- Understand the complexities of a watershed.
- Grasp the components that make up a watershed.
- Comprehend how one watershed can be very different from another one.
- See how the land use within a watershed can influence the health of the lakes and rivers of it.

Materials Needed:

- Computer and projector with internet connection
- Outdoor area to explore

Interest Approach: (five minutes)

Have students form groups of two or three. Within each group, have students try brainstorm a definition for the word “watershed.” After a few moments, see what the students came up with. Likely, answers will be something like the following:

“No idea at all.”

“A small building with a shower in the corner.”

“A shed full of water.”

“What you feel under a tree when it is raining.”

Hopefully, someone will say *“an area that drains water to a given stream, river, or lake”* as that is the proper answer.

Discussion: (fifteen minutes)

Explain to the class that no matter where you are outside, you are a part of a watershed. Water needs to flow somewhere when it rains. Water flows off of roofs, lawns, parking lots, and streets. All of these outdoor features are parts of a watershed. Ask the class why it matters to consider the role of a watershed. Discussion should include information about how the structures, land use, and topography of the land can all greatly influence the health of the water within a given watershed. Land use within a watershed means certain substances can wash into creeks, streams, rivers, and lakes, impacting the health of aquatic ecosystems and the quality of water. Emphasize how vital it is to consider the impact of watershed health when considering water quality. During storms and spring snowmelt, water washes residues from parking lots, lawns, fields, and roofs into

waterways, almost always without any treatment, impacting water quality. This can impact drinking water, recreation, the health of aquatic ecosystems, and more.

Emphasize with the students the concept of runoff, regardless of the surface yielding the runoff. Any situation where water is unable to be absorbed and it is flowing across the surface of something there is runoff.

Outdoor Exploration: (twenty-five minutes)

Take the class outside to explore the watershed elements of the land surrounding the school. When standing on some of the school's lawn, ask the class about what happens when it rains on that grass. Much of it will soak in, to the benefit of the grass. If it rains too much, what will happen? Explain runoff from lawns and ask the class if they can see any negatives from that. Answers will likely include:

"No harm can come from that as it's just water off a lawn."

"Some soil might erode where the roots are not strong enough."

"Maybe some extra fertilizer will run off when it rains too much."

Indeed, that can lead to some good conversation. Depending on where the runoff happens, it might not be an issue. Perhaps there's a spot where it can collect and filter. But, there is a creek near the grass and some nutrients from the fertilizer could wash into it. Explain also how even excessive leaves and grass clippings from mowing are able to contribute to lower water quality.

Bring the class up to a paved area outside the school, perhaps a parking lot. What happens when it rains here? How much soaks into the ground? Answers from students will usually include:

“None will soak in. It’s all paved. Total runoff for sure.”

“That plastic bottle might wash away.”

“Maybe some of that oil from under a car will wash away.”

No doubt about it, these are all great responses. It is a great opportunity to point out characteristics of impervious surfaces where no water is able to soak into the ground. Bring the class over to a storm sewer drain and point out how whatever flows into it will flow to a nearby river, creek, or lake without any treatment whatsoever. Furthermore, when water washes over such surfaces, it brings many things with it, including chemicals, sediment, and trash. Tie all of this together by comparing two major categories of pollution: point source and nonpoint source. Ask the class which is easier to identify – pollution in the form of chemicals flowing out of a factory’s pipe or pollution collecting off hundreds of acres of land? No doubt, the latter, which is non-point source pollution is harder to address since there’s generally not one particular contributor to the pollution. It’s many of the occupants of the land that play a role rather than one offending factory.

Conclusion: (five minutes)

Head back into the classroom and explain to the class how the next day’s lesson will focus on how land use can impact water health within a watershed and within the groundwater of a given area. Students should come to class with a list of characteristics

of the watershed where they live to start class the next day. Also, distribute permission forms for a field trip to a farm outside of town for one of the upcoming lessons of this unit as it will be a great opportunity to see what's being done about fertilizer management there. As the instructor, be sure that the field trip is pre-arranged for that day with the farmer and the agronomist he or she works with.

Lesson Four – Impact of Land Use on Water

Objectives ó Students will be able to

- See how farmland practices can contribute to compromised water quality.
- Consider residential impacts within a watershed.
- Further grasp the role of impervious surfaces within a watershed.

Materials Needed:

- Handout on the parts of a watershed (can be found in Appendix B)
- Computer and projector
- Soil probe
- Bags for soil samples

Interest Approach: (five minutes)

Have the students share what they observed about the watershed characteristics of their homes. Many will point out their lawns, others a farm field, some a parking lot or driveway. Hopefully a few bring up the changes in elevation on their land as that can certainly play a role. Explain how each of those components, including buildings, can all influence water health.

Discussion: (thirty-five minutes)

Distribute the "parts of a watershed" handout, as is found in Appendix B. Explain the various parts of a watershed as students complete the worksheet. Discuss the role of the land, a high elevation area to serve as the border or divider between watersheds, and the low area where water collects and flows. Consider the features of a watershed and how they impact its health. See if the students can think of the specific watershed that the school is a part of. Perhaps they can identify the nearby river where water flows in town. Use the computer and projector to show the United States Geological Survey's website on watersheds, found at http://water.usgs.gov/wsc/map_index.html to help the class trace the flow of water from the school to its destination within its watershed. Through a few simple steps with the website, you can pinpoint the flow of water from your specific location and trace it to its eventual destination.

Transition to the land use practices that can influence water quality. Many of the sources of concern in the state of Minnesota are connected to the use of fertilizers. Ask the class why fertilizers are important. Emphasize the need to produce food on our farm fields and how the science of soil fertility has led to significant increases in crop yields over the years. There are other factors that help, but fertilizer use is a huge factor.

Furthermore, similar practices come into play when homeowners and golf course groundskeepers want to achieve beautiful, green, healthy grass. Fertility of soil leads to healthy plants. That's not really a problem. However, be sure the students grasp that the issues arise when excessive fertilizers are used and they move down through the soil or across the soil into our water supplies.

At this point, students can understand the connection between land use and watershed health. It's the same reason why lakes and rivers in areas with forests on the land are usually healthier than those in farm country or urban settings. The risk is so much greater for fertilizer to be lost to ground or surface water. So, why would homeowners and farmers let this happen? Doesn't fertilizer cost money? Indeed, it does. Explain to the class that farmers strive to not waste fertilizer. It is not cheap and they want to use it efficiently. Plus, they're the ones using water in that particular area for their families and livestock, so they have a legitimate interest in being sure water is clean.

Notify the class of upcoming field trip plans. The class will be taking a trip to learn more about the technology that exists to address these problems in farming. And for the non-farm home or business owner? Well, let the class know that far too often, people think that if they use some lawn fertilizer it is good, so using more is even better when that is not really the case. Soils under lawns are like soils elsewhere so they may or may not need various nutrients and soil tests can be done to determine that.

There is another connection between nutrients and water quality and that is eutrophication. Ask anyone what they think of lakes that turn green as the summer rolls on and they'll surely all say that it's a problem. Much of that is due to excessive levels of nitrogen and phosphorus, which leads to algae growth in the pond and lake. The algae dies fairly quickly and then decomposes, along with other organic matter, in the water. That decomposition leads to loss of dissolved oxygen. Let the class know that along with the soil tests they'll be doing, they should bring in water from home or their favorite lake for dissolved oxygen testing in class. Explain that the water they bring in needs to be sealed in a container without any air bubbles.

Outdoors to Collect Soil Samples and Conclusion: (ten minutes)

As the class winds down, bring them outdoors and demonstrate the use of a soil probe to collect soil samples. Let students use the probe to collect, bag, and label soil core samples from the lawn outside the school. They should label where the soil was taken from on the bag. Before bringing the class in for dismissal, assign the class to bring in soil samples from home, either from yards or farm fields, to go along with the water samples they bring from home or a nearby lake.

Lesson Five – Testing Soil Fertility and Dissolved Oxygen in Water

Objectives ó Students will be able to

- Explain the role of major soil nutrients.
- Test soil samples and determine fertility needs of soils.
- Determine how lime can be used to neutralize acidic soils.
- Determine dissolved oxygen levels from samples collected.
- Connect dissolved oxygen levels in water to the health of a watershed.
- Learn what can be done to improve dissolved oxygen levels in a body of water.
- Work in groups to fulfill a lab task.

Materials Needed:

- Rapitest soil fertility lab kits to determine nitrogen, phosphorus, potassium, and acidity
- Soil samples
- Hand washing stations
- LaMotte dissolved oxygen in water lab supplies

- Soil fertility and dissolved oxygen lab sheets, as found in Appendix C and D

Interest Approach: (five minutes)

Show the class a sample of a lawn fertilizer bag's label. It should feature three numbers prominently. For example, it may read "11-5-24." Ask the class if they know what it means. Several guesses may speculate about organic matter or mineral content of the fertilizer. One might assume it's an expiration date. Perhaps someone will get it right and state that those numbers relate to the percentages of nitrogen (N), phosphorus (P), and potassium (K). Indeed, those are the big three macronutrients found in fertilizer that help plants thrive.

Introduce the Lab: (five minutes)

This class period is designated for some hands-on lab work with soil samples to determine their content of N, P, and K. There is also going to be a test done to determine the acidity, or pH of the soil being tested. With this number, students can consider future fertilizing needs. Explain the procedure and show where lab materials are available. Students will choose a partner and perform N, P, K, and pH tests on soil samples from their homes. For those who did not collect any samples, they can use the soil collected from the school yard.

A second part to the lab is to perform dissolved oxygen tests on water samples.

Hopefully many students brought in water from home in sealed containers without air bubbles for the test. Any who did not bring in water samples can collect water from sinks within the school for the quality tests.

Perform the Lab: (thirty-five minutes)

Give the students time to perform the hands-on lab exercises. Specific procedures for the soil and water tests are included in the lab sheets, which can be found in Appendix C and D of this document.

Circulate around the room and assist as needed. At the end of the lab, students are asked to use classroom computers or book resources to answer questions about the roles of N, P, K, and pH on plant growth and health. They are also expected to analyze results and determine what, if any, fertilizer is needed for the land where the soil was collected.

Remind the class what was covered during the soil unit weeks earlier about how fertilizer is applied and that lime is used to neutralize the pH of acidic soils.

There are also questions regarding dissolved oxygen in the lab. They relate to how dissolved oxygen can vary by season, how it impacts fish, what leads to high and low levels of it, and eutrophication in general.

Conclusion: (seven minutes)

Briefly discuss the findings of the lab with the class. Explain that if they didn't have time to answer all of the questions on the test that they have two days to finish them before turning them in for grading. Then, give a preview of lesson six in which the class will be going to visit a nearby crop and hog farm to learn about nutrient management and precision agriculture. They should report to the bus in the lot, prepared to be outdoors for the class. Furthermore, they should be on their best behavior for the trip and they must be mindful of safety on the farm at all times.

Lesson Six – Field Trip to a Farm

Objectives ó Students will be able toí

- Explain the steps taken by farmers to manage nutrients.
- Grasp how manure is applied to cropland.
- Comprehend the role that technology can play in precision agriculture to help the environment and water quality.

Materials Needed:

- School bus and driver
- Field demonstration areas relating to tillage and cover crops
- Tractor with global position system (GPS) setup
- Manure injection equipment
- Strip tillage equipment

Load the Bus, Travel: (ten minutes)

Please note that for the sake of maximizing the educational potential of the field trip, it is suggested that arrangements be made to make the field trips two class periods long.

Rather than attempting to fit travel time and the educational tour of the farm into one fifty minute block, get permission from other teachers for students to miss the class period either before or after to extend the tour. Also, prior planning is necessary to secure the bus and arrange the tour. Ideally, work with a farmer who has livestock and has up-to-date technology practices regarding crop production. Planning the topics to be discussed with the farmer prior to the field trip is an important step to this experience as well.

Meet the students in the school lot, take attendance, and head to the farm. Be sure students are dressed appropriately along the way. Give a brief preview while on the bus. This tour is about seeing precision agriculture equipment, various types of tillage, the potential of cover crops, and how manure can be applied to fields. Connections will be made to water quality during and after the field trip.

At the Farm: (one hour and twenty minutes)

Meet the farmer near the farm shop and allow a basic introduction to the class. He or she will give an overview of their operation, including the acreage of cropland they raise each year in corn, soybeans, and alfalfa as well as the number of hogs they raise on the farm. These hogs relate to a great amount of manure production. Of course, that can be used for fertilizer on the cropland. At this point, the farmer can show how manure is applied to the field. While it used to be sprayed in liquid form on the surface of the ground, it is now injected. The class is brought over to the tractor with the manure injection implement hooked up. In the near distance, a field where manure was recently injected is visible. All of the manure was applied below the surface of the ground. Be sure to ask the class what the advantages of that practice are. It's important that they grasp the value of not having it all on the surface where there is potential of runoff during rains. Furthermore, odor from the manure is reduced through injection and neighbors appreciate that a great deal. Another good point that the farmer is likely to make is that he or she will actually get a nutrient analysis done on the manure to know its content and plan where to inject appropriately.

The next phase of the tour brings the class to the edge of some of the fields. One area features several acres planted to cover crops, then there are tillage plots set up to demonstrate various tillage practices. The cover crops feature tillage radish, rye, and a few other plants that were a part of their mix. The farmer explains that the cover crops were planted in mid-August on land where spring wheat had been grown. Since it is harvested earlier than other crops, there is enough time to justify planting cover crops for the land.

Then, it's a good time for the class to discuss the advantages of cover crops. They keep nutrients in the field, reduce erosion, and break up soil compaction. At that point, students in the class should go pull up some of the radish plants to observe the deep tap roots they send into the ground. Those roots can break up a compacted layer of soil that often develops in farm fields. How does all of this impact water quality? The farmer can explain that keeping nutrients in the field for future plant growth reduces the amount lost from a field that might reach surface and groundwater. Water quality is also connected to the reduced erosion in cover crop areas. When soil erodes it often reaches creeks and lakes, adding to the sediment load of those waters.

A good question to ask of the farmer at this point is if there are any other times when cover crops are used in Minnesota. Indeed, he or she should explain that in years with wet springs, there are often many acres unable to be successfully planted to the intended crop. Using cover crops on those areas is a smart strategy to ensure soil and water health while reducing weed issues and keeping the soil prepared for future plantings.

After examining the cover crop plot, the class then walks over to the tillage plots. One plot features corn grown in a no-till situation. Another shows conservation tillage where considerable crop residue was left on the soil surface before soybeans were planted. A third area demonstrates full-scale tillage where corn was planted in a traditional method. Finally, a portion of a field is set up to demonstrate strip tillage practices. To complement these demonstration areas are the accompanying pieces of equipment and technology tools like a laptop and tractor GPS components.

First, bring the class to the no-till corn field. The farmer will explain how the planter was used to plant corn into the stubble of the barley crop from last year. The soil surface remained permanently covered by what was left of the barley stems from last year. Relatively few weeds developed and the ground was never exposed, risking erosion and leading to higher water quality through reduced runoff issues. The farmer does explain limitations of the system, relating to slower soil warm-up in the spring and concerns about pest-buildup in the soil. Plus, the planter needs to be setup for it.

The next crop plot is featuring mulch tillage where the ground was given some tillage with a chisel plow before soybeans were planted. The farmer explains how around 40% of the corn stubble from last year's crop remained on the ground, mainly in the form of pieces of corn stocks. A major benefit of this type of conservation tillage is that early season rains don't just hit bare soil and are often slowed down by hitting the corn stubble. That slows down erosion and keeps soil and other nutrients from running off the land into water and impacting its quality. Technically speaking, around 30 percent of the previous crop's residue should be left on the soil surface to be considered conservation tillage and the farmer explains that the goal is to exceed that number when possible.

To show what was once very common, and still is done a great deal, the farmer has an area set up to show full-scale tillage. In this area, a mold-board plow was used to fully turn over the old crop and leave primarily black dirt exposed on the surface. This is still common in Minnesota because soil temperatures rise faster in the spring with more of the black dirt exposed to the sun and air. That leads to earlier planting dates and often times higher yields. But, as the farmer explains, the risks of soil erosion do increase in that type of farming. Anytime soils and nutrients wash off the land, there's a risk to water quality. Nutrients can reach water and soil particles in water can lead to increased levels of turbidity in lakes. Fortunately, as the farmer explains, many fields on Minnesota feature soils that are not too prone to erosion and make this type of tillage more of an option than would be the case in other regions.

Lastly, it is time to learn about some new technologies in farming that can lead to maximum nutrient efficiency and environmental benefit. The farmer explains how he or she works with a local agronomist to take soil and plant tissue samples to assess nutrient needs. This data can indicate where various nutrients are sufficient or deficient in a field. Soil types are also taken into account. This leads to the option of utilizing prescription application of fertilizers in fields based results from these tests. The farmer shows some field maps and data to students to explain how this works. In the end, the farm is able to spoon-feed nutrients where they are needed and avoid excessive application where they are not needed. This all ties in with GPS technology in the tractor that can help steer the machine and apply variable-rate fertilization of the land.

Taking this to another level is the use of strip-tillage. The farmer then shows the class his or her strip-tillage plow. The great thing about this machine and precision agriculture is

that they can go into a field in the fall and place fertilizer in the ground in narrow strips, spaced out to match the spacing on their planter's row units. Fertilizer is applied in the ground so it won't wash away and crop residue is left relatively undisturbed on the soil surface. In the spring, they can synch the planter up with the data from the fertilizing they did in the fall with the strip till plow and plant right into those fertilized strips. Plant roots can access the food they need in the ground and chances of erosion and loss of nutrients is very low, all leading to responsible water and soil management. In the end, runoff from the field is truly minimized. Then, the farmer explains that the downside to precision agriculture is the start-up expenses as the equipment does not come cheap. Still, doing the right thing for the land will always pay off in the future.

As the farm tour winds down, the class is shown a few areas where the farmer planted with the contour of the land and has used grass waterways to minimize erosion and assure water and soil health in the area. Also, before departing the farmer shows the class the buffer strip that he maintains near a drainage ditch on the land to be sure runoff from the field near it does not reach the field. And, the group of students is told to be sure to observe the land on our drive back to the school that is no longer in crop production. It is acreage now enrolled in the Conservation Reserve Program and it has been restored to native grasses. Wildlife love it and it's a great spot for hunting. Plus, water quality does benefit since it now features permanent vegetative cover.

As the class heads to the bus, they should thank the host farm for their time to make the tour interactive and educational.

Travel back to the school: (twenty minutes)

Watch for the land in the Conservation Reserve Program along the drive. Also, reflect on the educational experience at the farm and how it relates to the potential of modern technology to help farmers reduce their impact on waterways. Consider how important it is that farmers continue to implement technology to reduce runoff from the land. And, as a part of the reflection with the class, discuss how conservation tillage, grass waterways, and buffers can truly mitigate nutrients reaching waterways and groundwater.

Lesson Seven – Urban Connections to Water Quality Issues

Objectives ó Students will be able to

- Understand water quality issues linked to non-farm places, like cities.
- Further see the roles of impervious surfaces with nonpoint source pollution.
- See how wetlands and bio-retention areas can help water quality.

Materials Needed:

- Quiz to give the class on farm-related water quality efforts, found in Appendix E
- Parking lot with adjacent bio-retention area

Review Previously Covered Information and Give Quiz: (ten minutes)

Recap the concepts covered in the previous lesson about all of the potential of modern technology to reduce farming's impact on water quality. Be sure to discuss buffers, conservation tillage, and precision agriculture practices relating to planting and fertilizers, as well as manure injection.

After reviewing water quality connections to farming, give the class a quiz on that information to assess student comprehension of the information covered thus far in the unit. The quiz can be found in Appendix E.

Introduction to Urban and Residential Water Quality Issues: (thirty-eight minutes)

Remind the class of the watershed and parking lot runoff topics covered earlier in the unit of study. Whenever rain hits a parking lot, whatever is there has the potential to wash into storm sewers and nearby waterways without being treated at all. This is all compounded by the square footage of roofs and roads in towns and cities. Those are all impervious surfaces and water will run off of them.

Bring the class outside for a demonstration relating to runoff. Sprinkle sawdust on the pavement to represent lawn fertilizer and then pour water over it to represent rain. As the class watches the sawdust wash off the pavement into the grass nearby, explain that whenever lawn fertilizers are accidentally spread on sidewalks, driveways, or streets it will wash away in a rain and contribute to water quality issues.

A great example of fertilizer issues in water is phosphorus, as well as nitrogen. Ask the class what they think of lakes in late summer that have green algae all over the place.

Very few students will say they appreciate it. It's unsightly, results in poor environments for fish, and can be a threat to the health of visitors. Phosphorus and nitrogen reaching lakes are a major contributor to these algae blooms and contribute to eutrophication of a body of water. Explain to the class that for that reason, in some places, phosphorus is not even allowed to be included in lawn fertilizers.

The whole concept of impervious surfaces and runoff during rain events can also contribute to flooding issues. Runoff issues from impervious surfaces are compounded by our reduced amount of wetlands and fewer places for water to soak into the ground. Some solutions are coming into place as many construction sites are now required to construct bio-retention basins near parking lots and roads. These allow water to collect that would otherwise flood streets, storm sewers, and streams.

Lead the class outside to observe and discuss a bio-retention basin connected to a parking lot near the school. It's a great example of local efforts to improve water quality, recharge groundwater, and reduce flooding. Return the class to the school.

Conclusion: (two minutes)

Give a brief preview of lesson eight's plan to have a guest speaker from the local Soil and Water Conservation District. Encourage students to think of questions they may want to ask our expert visitor.

Lesson Eight - Guest Speaker

Objectives ó Students will be able to

- Learn about ways of collecting rain water to reduce flooding and benefit wildlife.
- Understand the potential for aesthetically-pleasing water management practices.
- Grasp the advantages of green roofs.
- See how there are alternatives to traditional impervious surfaces.

Materials Needed:

- Porous concrete demonstration model

- Visuals of types of parking lot systems
- Visuals of green roofs and bio-retention areas
- Plastic rain barrel
- Pitcher of water

Interest Approach: (three minutes)

Show a series of pictures on the projector in the classroom. These photos should include a green roof, a bio-retention area, rain gardens, rain barrels, and porous concrete. Ask the class what each of these things has in common. Hopefully they will see the connection that each of these things can help manage water to improve water quality in towns and cities. Next, transition to the guest speaker by introducing them to the class. This is ideally an individual who represents the county's Soil and Water Conservation District.

Guest Speaker Time: (forty-five minutes)

The general format of the time with the guest speaker should follow this outline:

1. Background information
 - a. Educational background
 - b. Personal connection to resource conservation
2. Day-to-day work as a conservationist for the county
 - a. Role of the county Soil and Water Conservation District
 - b. Work with community members
 - c. Developing and implementing plans
 - d. Educational projects within the county

- e. Restoring wetlands, soil and water programs for landowners and construction sites
 - f. What average citizens can do to make a difference in soil and water health
3. Demonstration of porous concrete and permeable pavers
- a. Set-up a section of porous concrete in the classroom
 - b. Pour water over the concrete and allow it to collect in a tub below
 - c. Discuss the implications of additional porous concrete relating to reduced runoff
 - d. Point out other options, such as pavers which allow water to soak through into the ground
 - e. A great example of alternatives to traditional parking lots can be found at the University of Minnesota Landscape Arboretum in Chaska, MN at their runoff model
 - i. Fully impervious surfaces have 100 percent runoff
 - ii. Other parts of the model feature nearly 100 percent infiltration of rain water and very little runoff
4. Share designs and plans for rain gardens and bio-retention areas
- a. Be sure students see how these are aesthetically-pleasing options for commercial and residential properties
 - b. Point out ideal plants for these areas
 - c. Bring up positives of collecting rain, filtering water, reducing flooding, and providing habitat for wildlife
5. Show a visual of the layers of a green roof

- a. Want to cut down on urban heat issues, beautify, and create oxygen? Set up a green roof
 - b. Plants growing on roofs can use up water rather than let it all wash off a roof, beautify, and provide photosynthetic services
 - c. These are practical for Minnesota and can last for decades
6. Bring the class outside to see a rain barrel
- a. Why not save money on your water bill by using water from your roof?
 - b. A rain barrel is an affordable way to collect rain water
 - c. Demonstrate how easy it is to set one up by a downspout from a roof
 - d. Explain that this is basically a smaller version of what is being done at Target Field in Minneapolis
 - i. Rain water is collected from parts of the stadium
 - ii. The water is used to irrigate and wash the lower level of the stadium
 - iii. This makes the stadium very sustainable and reduces water needs of the property
7. Question and answer time with the guest speaker
- a. Allow students to ask questions about information presented by the speaker
 - b. Be sure to explain how some of these options benefit everyone in the community and are legitimately practical options to consider

Conclusion: (two minutes)

Be sure the class expresses their thanks to the guest speaker for sharing their time and expertise. Let the class know that the next lesson will be a review of information covered in the water quality unit of study in preparation for a test.

Lesson Nine – Review Game

Objectives ó Students will be able to

- Recall important facts and concepts relating to water quality in Minnesota from the unit
- Prepare for the unit test

Materials Needed:

- Computer with projector
- Jeopardy-style review game with water quality questions, as found in Appendix F

Introduction: (five minutes)

Let the class know that they will be playing a review game. It is wise to pay attention to all questions because every question in the game could help prepare them for the upcoming test. Proceed to divide the class into teams for the game. Go over the rules of the game:

- Control of the game will circulate around the room. Team one gets to pick first, then team two, and so on.
- If a team gets a question wrong, the next team can steal it. If they get it wrong, it goes to the next team, until someone gets it right. If no one gets it right and all teams have had a chance, the teacher gives the answer.

- After completing all available questions, the teams have a chance to wager their points on a final round question.
- The top two teams earn extra credit points on the upcoming test.

Game Play: (forty-five minutes)

Conduct game play with the class. When possible, explain additional information with a given question and answer to maximize the value of the review exercise. You will find the review game PowerPoint slides in Appendix F of this document.

Conclusion: (five minutes)

Remind the class that the unit test will be tomorrow. Answer any last questions the class has on the topic at hand. Let the class know that the test will be in the usual format of multiple choice questions, some true/false statements, and a few short answer questions.

Lesson Ten – Unit Test

Objectives ó Students will be able to

- Demonstrate their knowledge and understanding by doing well on a comprehensive unit test.
- See their personal roles in water quality issues.

Materials Needed:

- Unit tests on the topic of water quality, as found in Appendix G
- Modified versions of the test will be needed for students with special needs requirements

Introduction: (three minutes)

Remind the class of the rules of test-taking in class:

- Eyes on your own test and never on anyone else's test
- If you have a question about anything on the test, come to the teacher
- No notes are allowed during test-taking
- Students must be quiet during the test
- When done, turn in the test and quietly work or read at your desk

Give the test: (forty-five minutes)

Pass the tests out to the class and give the students time to complete them.

Conclusion: (two minutes)

Once all tests are turned in, wrap-up the unit with the class. Remind them of the role that each citizen plays in the water quality of our area and other parts that get their water from our area. Also bring up the interconnectedness of resources to water. If we care for water, we care for creatures that depend on it beyond humans and we make a sound investment in caring for our future.

CHAPTER FIVE

CONCLUSIONS AND DISCUSSION

Introduction

The topic of water quality in Minnesota is very popular in the news. At times, articles just state the issues and other articles are able to point out potential solutions. In some instances, these solutions are legally required of landowners, such as the regulations relating to buffer strips of permanent vegetation along drainage ditches. Other times, it is up to individuals to become educated and make a difference on their own. That is why curriculum like the lessons included in this project are remarkably relevant. They tackle important topics and teach key strategies that each student can utilize to be more informed citizens who can make more responsible decisions. And, since these decisions will gradually result in higher water quality, everyone will benefit in the long run from more people making sound water-related choices.

Conclusions

In my career I have found that students learn in a variety of ways. In some cases, traditional book work, lectures and note-taking works out well. Many others thrive with hands-on learning opportunities. And, it's nearly always worked out well to have guest speakers who are experts in their field visit classes. They are able to bring a perspective to the class that only someone in their respective profession would be able to do. Another great way to take learning to another level is to incorporate field trips. I have been able to foster several local relationships with people to make field trips happen. It's these experiences that stand out in the memories of students without a doubt.

Given that students learn in a variety of ways, to really get a concept to sink in with your audience, approach the subject matter in multiple methods. Start the topic out with classroom lecture, discussion, and assignments. Supplement with hands-on lab work since it is safe to say that doing a given task or experiment really leads to students seeing the relevance of the information. Additionally, drive the point even further home with guest speakers and field trips. By teaching the content with multiple techniques, students should all learn it well regardless of their educational strengths.

The contents of Chapter Two reveal the most pressing issues of water quality as well as ways to teach the information to students. It served greatly to guide the development of the curriculum based on what information was most important to include and how it should be taught. Knowing what others have developed in the past was a solid guide to take into consideration. Furthermore, my methods of using guest speakers, field trips, and hands-on learning were validated through the research that proved their value.

In the end of this unit, each student should be walking away with valuable knowledge of Minnesota's water quality issues and potential solutions. Each student has the power to make a difference. It can be as big as being smart with fertilizers in a corn field or fertilizers for a small lawn. Everyone can do their part to impact a watershed positively. That is really the goal in the end with this curriculum.

After completing this curriculum, I see a limitation in the fact that there is not more relating to wetlands in the curriculum. There's so much that can be learned about various types of wetlands, how they benefit the environment and water quality, all while providing wildlife habitat. Honestly, a study of wetlands could be a whole unit of its own

in natural resources curriculum. Additional observations and study of a river or creek would also be nice as such activities could be insightful to health of aquatic ecosystems.

Potential Variations to this Curriculum

I am relatively fortunate in the sense that field trips are a feasible option for me with my school. Bussing is not much of a challenge and there are several local sites willing to host student groups. Not everyone has those options. Still, even if one local field trip is all that can be fit into this unit in a given school, it is a very memorable and impactful experience for students. A potential alternative is to do a field trip on foot option. Perhaps there are sites that can be walked to easily within the timeframe of a class period. There might be a nearby stream or parking lot catch basin that can be visited easily. Maybe it is a country located in the country where farm field access is adjacent to the school's property. Getting students up and outside is almost always a good idea. Far too many hours are spent in chairs in classroom and teachers in natural resources classes can do something to reverse that trend.

Preparing for this Unit

Anyone using this curriculum should be aware of some pre-unit planning that needs to be done to make various components take place. Acquiring lab supplies for the hands-on lessons might require ordering lab kits in advance or restocking old supplies. Arranging for the field trips would mean scheduling a bus and driver. If the field trips are going to go beyond the traditional class period, provisions need to be made with other teachers regarding students missing classes for the trip. Of course, arranging the actual trips needs to be done in advance. No farmer wants a bus of students just showing up, so planning that trip ahead is a must.

It's always also wise to book guest speakers for your class weeks in advance. They're generally always making room in their busy schedules to fit in visits to classes and you need to work around that. The good thing is that many people are usually more than happy to visit students. They know it's in the best interest of their profession to educate and promote within the high school setting.

Final Thoughts

I learned a lot through my research about water quality in the news, water quality solutions, what educational resources already exist, and what educational strategies are ideal. It is important to teach units on soils and an introductory unit on water prior to this water quality unit. There are several connections to water basics and soil characteristics that are made during this unit. I look forward to utilizing this curriculum in future years of teaching. I know it will suit the needs of my students for a long time to come. Of course, as the need arises, I will tweak details of the lesson plans. New technology will take on an ever-increasing role in how I teach. Resources and procedures will change. What I hope does not change is the aspect that gets students up and moving, going outside, doing hands-on tasks, and approaching important topics with inquisitive minds.

As time allows, I would like to revisit this curriculum and conduct additional research. It's entirely possible that some of the water quality issues of 2016 will be resolved in the next ten years. In fact, some of the problems could be solved in less than a decade. It's also true that farmers and those caring for lawns will become wiser with the use of fertilizers. The same goes for the use of road salt, how parking lots and roads are managed and constructed, and how rain water is handled. Hopefully the issues of the future are quite different, and perhaps less concerning, as the issues of today are

gradually addressed. It should also be noted that technology will continue to change, demands on the land and farmers will increase, and weather patterns are going to continue to impact water quality. Certainly, future research on these topics would be interesting and would be an important part to keeping this curriculum relevant in the years to come.

As I reflect on this curriculum, it's important to consider possible methods of informing other teachers of its existence. One of the goals of this work is that it be used, and not just by me in my classes. I intend on spreading the word about this curriculum with other teachers who I know conduct lessons on natural resource topics. I am an active member of the Minnesota Association of Agricultural Educators and I strive to attend conferences annually. At these conferences, the opportunity routinely arises to share information with other teachers about curriculum. It would be a great place to let others know about this work. Additionally, when the opportunity presents itself, I will let natural resources professionals know about the curriculum so they might be able to use it or let other teachers know of its existence. Furthermore, having this curriculum available through Hamline University's online resources, really opens up its availability to other teachers for future use.

Just how far reaching can the impact of this curriculum be? There's certainly a great deal of potential. Today's high school students are tomorrow's concerned citizens, taxpayers, homeowners, business owners, and politicians. Their attitude and actions will influence the direction of water quality for generations to come. Environmental policy might be influenced to bring about change. Also, teachers in many schools could use this

curriculum to have a similar impact on students as well. Indeed, the impact could be far-reaching within the education system and society as a whole.

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APPENDIX A: Water Consumption Table

Water Consumption Table

(All values are approximate)

3.65 gallons (12.620 liters)	Flushing a toilet
3 gallons (12 liters)	Shaving and letting the water run
5 gallons (20 liters)	Shower per minute
8 gallons (30 liters)	Cooking three meals
8 gallons (30 liters)	Cleaning house
10 gallons (40 liters)	Washing dishes (three meals)
20.630 gallons (75.6115 liters)	Washing clothes
30.640 gallons (115.6150 liters)	Watering a lawn
30.640 gallons (115.6150 liters)	Taking a bath
30.640 gallons (115.6150 liters)	Washing a car

Source: Project WILD Aquatic

APPENDIX B: Watershed Visual Handout and Concepts Questions

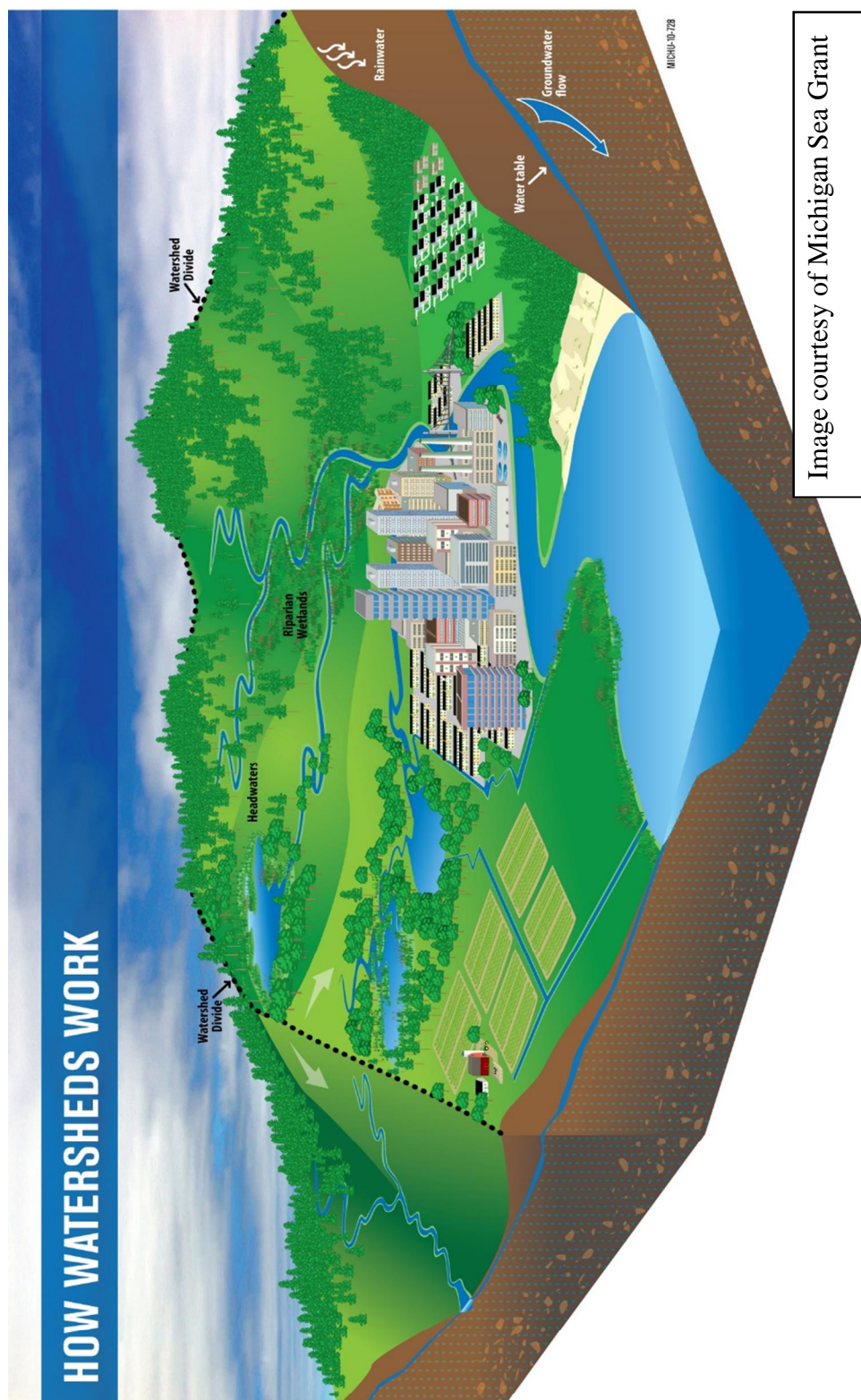


Image courtesy of Michigan Sea Grant

WATERSHED CONCEPTS

What is a watershed divide?

Identify three different uses of land found in the picture.

How do those uses of land impact flow of storm water?

How are do natural landscape features impact water differently than manmade structures?

Where is nonpoint source pollution likely to impact water quality negatively?

APPENDIX C: Soil and Water Testing Lab Assignment

Names: _____ Natural Resources

Date: _____ Soil Nutrient Testing and Water Dissolved Oxygen Testing

PART ONE 6 SOIL NUTRIENT AND ACIDITY TESTING

Introduction:

There are three major soil tests that can be done to determine the fertility of soil. They are acidity (pH), nitrogen (N), phosphorus (P), and potassium (K). Potassium is also shown as ðpotashö as levels of potash indicate K levels. Plus, potash is what is usually applied to increase K levels in soils. Each of these characteristics determine how well soil will support certain plant life and let you know how much and what kinds of fertilizer to possibly add. If your land is found to be acidic, spreading lime is a common remedy.



Each group to perform the following tests in class:

pH - green N -purple P -blue K -orange

The class will split into groups, based on who had brought in soil samples to class. Those who didn't bring any samples in will test soil samples collected from outside the school.

Procedures and Safety:

Follow the steps on the two-sided information sheet each group was given to perform the soil tests. Be sure of the safety requirements associated with this lab that are listed in your handout.

Be aware that procedures require water to be mixed with soils, and then allow the soils to settle for the soil tests. Be sure to answer questions in this assignment while your water settles. Use book or online resources to find this information.

Source of Soil: _____

Describe the water after 10 minutes of settling time:

pH Results:

N Results:

P Results:

K Results:

Follow-up questions:

1. Compare your findings to the other groups. Are there differences between the soils? Any interesting findings?
2. Is the soil suitable for any type of crops, garden plants or grasses? If not, what should be added to help it?
3. What role do macronutrients play in plant growth and health for the following nutrients:
 - a. N ó
 - b. P ó
 - c. K ó
4. There are micronutrients that plants also need. List at least three micronutrients.
5. What can happen if excessive levels of nutrients are applied to a field, garden, or lawn?
6. Based on your findings for the soil you tested, what fertilizers should be applied for the upcoming growing season if you're growing either a lawn or vegetable crop?
7. If your soil is acidic, what amount of lime should be applied to neutralize the soil?

PART TWO 6 DISSOLVED OXYGEN TESTING OF WATER

Definite links have been found between a lake's dissolved oxygen level and the health of it for fish and other aquatic organisms. Excessive nutrient loads in lakes can eventually lead to algae growth, organism death, and then decomposition of organic matter. Perform the LaMotte Dissolved Oxygen in Water Lab based on the specific directions in the booklet given to your group. Be mindful of safety practices.

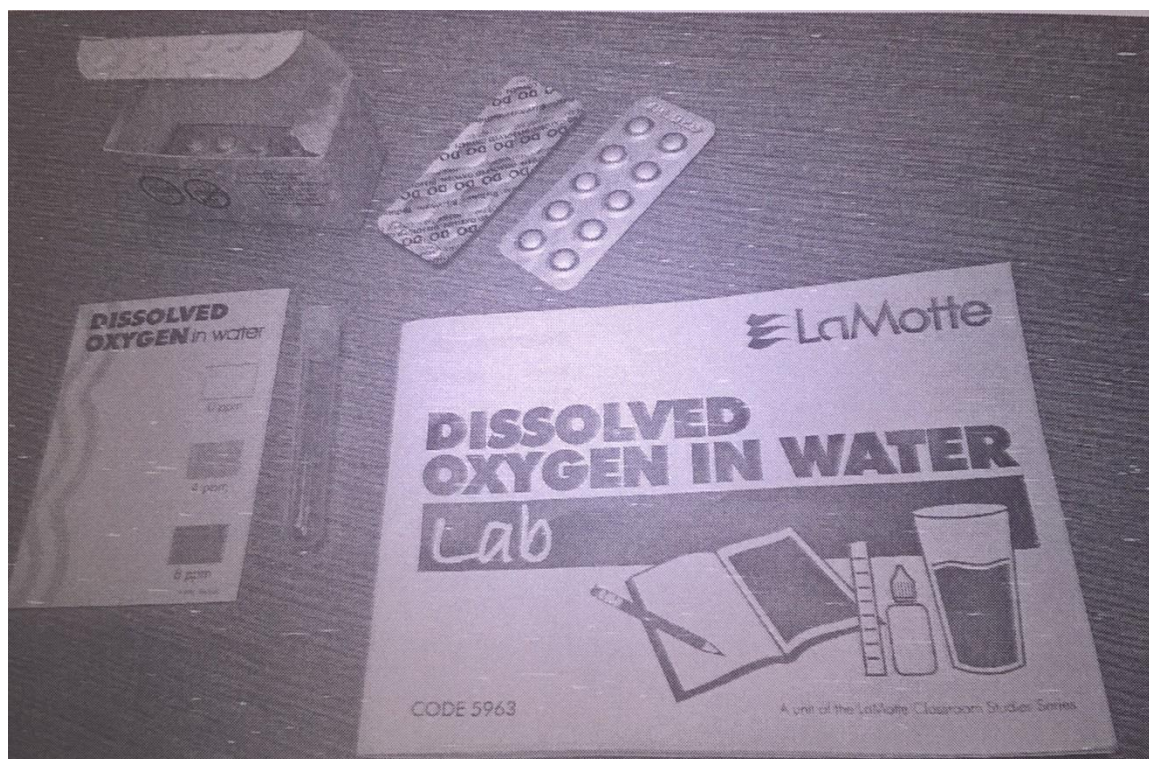
Source of your water sample: _____

Perceived health of source of your water sample prior to the test: (consider your observations of the source: was it clear, was there algae, was it standing water or flowing, etc.?)

Procedures, Safety:

Follow the steps to test the water based on the handout given to your group. Be sure you don't have a bubble of air in your vial of water. Be mindful of safety rules.

Dissolved Oxygen in Water Lab Kit Information:



SAFETY

- 1** Follow the instructions. Read to the end of each procedure before starting the actual work. Measure samples and reagents accurately. Add the reagents in the order stated in the instructions. Observe the waiting times, when specified, for maximum color development.

INSTRUCTIONS
- 2** Read reagent labels and Material Safety Data Sheets when supplied. Avoid contact between reagents and the skin and eyes. Additional information for all LaMotte reagents is available 24 hours a day from the Poison Control Center listed in the front of phone book. Each reagent can be identified by the four digit number listed in the upper left-hand corner of the reagent label, in the contents list and in the test procedures.

Sodium Thiosulfate
- 3** Cap reagent bottles after use to avoid contamination. Do not interchange caps. Store reagents in a cool, dry place.
- 4** Rinse test tubes and caps thoroughly in clean tap water after each use. Allow them to dry before putting them away.
- 5** Store equipment and reagents out of the reach of very young children.
- 6** Wear eye protection during the demonstrations. Wash hands after performing the experiments. When using materials not contained in this kit, be sure to follow the safety instructions on the container.

After Testing

All reacted samples can be poured down the drain with lots of running water.

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WARNING! This set contains chemicals that may be harmful if misused. Read cautions on individual containers carefully. Not to be used by children except under adult supervision.

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2

KIT CONTENTS

QUANTITY	CONTENTS	ORDER CODE
50	*Dissolved Oxygen TestTabs	*3976A-H
5	Vials, glass, w/caps	0125
5	Color Chart	5963-CC
1	Manual	-----

*WARNING: Reagents marked with an * are considered to be potential health hazards. To view or print a Material Safety Data Sheet (MSDS) for these reagents go to www.lamotte.com. To obtain a printed copy, contact LaMotte by e-mail, phone or fax.

To order individual reagents or test kit components, use the specified code number in the list above. To order a complete refill for the kit, use code number R-5963.

3

A set of items for each team can be collected ahead of time and packaged in a zipper-top bag. Each team will need:

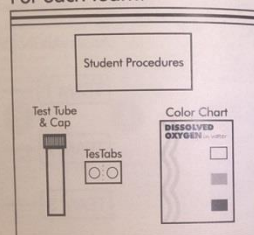
2	*Dissolved Oxygen TestTabs	*3976A
1	Vial, glass, w/cap	0125
1	Color Chart	5963-CC
1	Student Procedures	-----



TestTabs

TestTabs are supplied in strips of ten tablets. Before class, cut the TestTabs as shown at left and place in zipper-top bags with other apparatus for each group. Do not break the foil sealed pocket around each TestTab until ready to use.

For each team:



6

INTRODUCTION

Almost all types of water have some oxygen dissolved in them. Oxygen generally enters the water in two ways: from contact with the atmosphere and from aquatic plants.

Oxygen dissolves directly into water from the air at the surface of the water. Because more of the water's surface is exposed to the air in a tumbling mountain stream or a windswept, wave-covered lake, the water can absorb more oxygen than a calm, smooth body of water.

Dissolved oxygen is so important to the health of fish that aquarium owners and fish farmers often use mechanical methods to add oxygen to the water. They pump air through the water and use bubblers, diffusers or air stones to produce many small bubbles, increasing the amount of surface area for contact between the air and water. The rising bubbles also move and mix the water, allowing more water to contact air at the surface, increasing dissolved oxygen levels.

Aquatic plants, including algae, increase dissolved oxygen levels in water. During photosynthesis, plants use carbon dioxide from the water and energy from the sunlight to produce oxygen. On a sunny day, bubbles of oxygen can be seen on the leaves of aquatic plants. Since photosynthesis requires light, plants don't produce oxygen during the night but respire and remove a small amount of oxygen from the water which slightly decreases oxygen levels.

Dissolved oxygen levels change according to the time of day, the temperature and the weather. Water can hold more oxygen at low temperatures. Fish, like trout, may seek cold, deep pockets of oxygenated water. Salinity and altitude also limit the amount of oxygen that can be dissolved in water. Fresh water can hold more oxygen than salt water and the greater the atmospheric pressure the more oxygen the water will hold.

ppm (parts per million) is a unit of concentration for very dilute solutions. It is a way of expressing how much of something is in a solution. Parts per million is very similar to percent. 1% is one part per hundred. 1 ppm is one part per million. In water testing, ppm is also called milligrams per liter (mg/L).

7

Once in the water system, oxygen is used by the aquatic life. Oxygen is also consumed when organic material such as human or animal waste, improperly treated wastewater or plant debris decomposes in water. Bacteria use oxygen to chemically change the organic matter and break it down. This is called the Biological Oxygen Demand. Some aquatic systems may undergo such a large amount of decay of plant and animal material that no oxygen remains for the living organisms.

In natural water, a high dissolved oxygen level is a sign of a healthy ecosystem. Low dissolved oxygen levels are often a sign of pollution. The amount of oxygen required for growth and activity of a diverse population. Concentrations of 5 to 6 ppm are usually required for growth and activity of a diverse population. Dissolved oxygen levels below 3 ppm are stressful to most aquatic organisms and levels below 2 ppm will not support fish. Fish and other animals that can move will leave areas with low dissolved oxygen and go to areas with higher levels. Those that cannot move or are trapped may die if oxygen levels become too low.

High levels of oxygen are not desirable in water used in industry. Rust occurs when oxygen comes into contact with iron. As a result, even tiny amounts of dissolved oxygen contribute to corrosion in boilers and hot water heating systems. To prevent damage to these systems, chemicals called oxygen scavengers are added to absorb the oxygen from the water.



8

How To Take Water Samples

1

Test samples for dissolved oxygen as soon as they are collected.



2

If the sample is not going to be tested immediately, the container should be filled until it overflows, and then capped. This procedure eliminates the possibility of getting air bubbles in the sample.

3

Use a clean glass or plastic container.



4

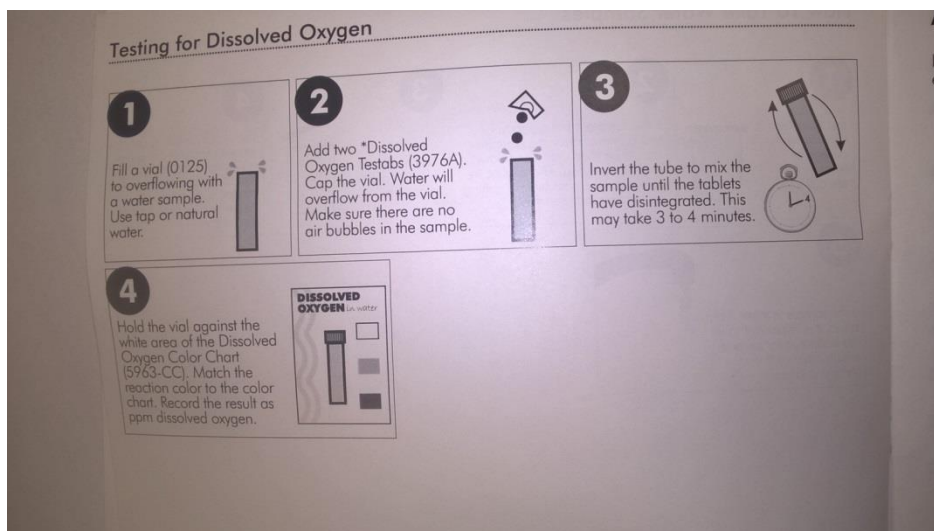
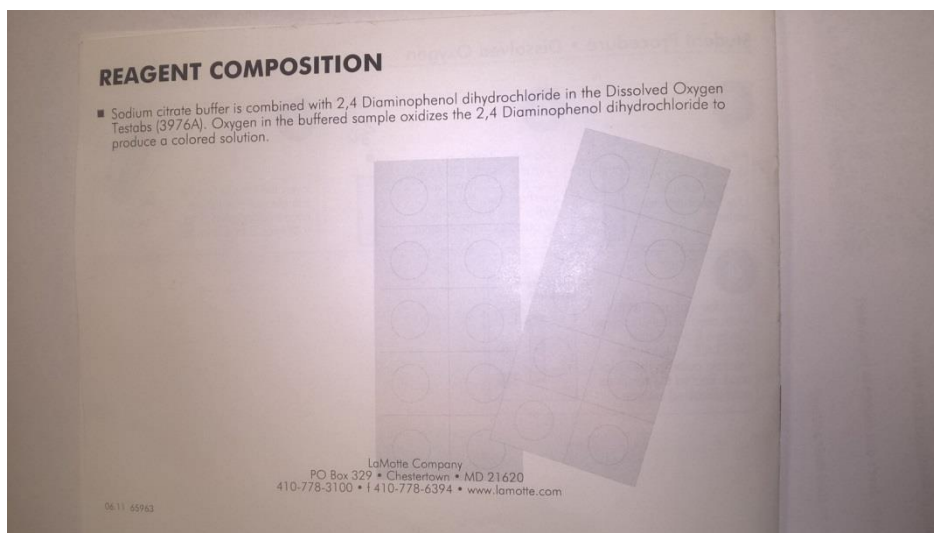
The water sample should be representative of the source. A natural water sample should be free of any foreign matter, such as aquatic plants and sediment from the bottom.

5

If the sample is taken from a tap, it is important to let the water run for several minutes before the sample is taken.



9



Match your water's color to the color chart.

Level of D.O. in your sample: _____ ppm

Water Follow-Up Questions:

1. What does your test result say about the health of the aquatic environment where you collected the water?
2. Why do you need to avoid having an air bubble in your vial for the test?

3. At what level of dissolved oxygen do fish start to feel stress?
4. What can be done to increase D.O. levels in a lake?
5. What leads to decreased D.O. in a lake?
6. What role does temperature play in D.O. levels?
7. Explain the phases that lead to Lake Eutrophication.
8. How can a watershed impact a lake's health?

APPENDIX D: Specific Soil Test Kit Instructions



rapitest Soil Test Kit

Products for Successful Gardening™

USING THE RAPITEST SOIL TEST KIT

This Rapitest Soil Test Kit is designed for simplicity of use and accurate results. At the heart of the system are 4 patented, specially designed testing devices called "color comparators" - one each for pH, Nitrogen, Phosphorus and Potash. Each comparator has a removable film color chart and color coded top. Capsules for each test are also color-coded.

PREPARING YOUR SOIL SAMPLES

For lawns, annuals or house plants, take the soil sample from about 2-3" below the surface. For perennials especially shrubs, vegetables and fruit, the sample should be from 4" deep. Avoid touching the soil with your hands. Test different areas of your soil, as it may differ according to past cultivation, underlying soil differences or a localized condition. It is preferable to make individual tests on several samples from different areas, than to mix the samples together. Place your soil sample into a clean container. Break the sample up with the trowel or spoon and allow it to dry out naturally. This is not essential, however it makes working with the sample easier. Remove any small stones, organic material such as grass, weeds or roots and hard particles of lime. Then crumble the sample finely and mix it thoroughly.

pH TEST:

1. Remove the cap from the green comparator. Make sure the color chart (film) is in place.
2. Fill test chamber to soil fill line with soil sample.
3. Holding the capsule horizontally over the test chamber, carefully separate the two halves of the green capsule and pour powder into the test chamber.
4. Using the dropper provided, add water (preferably distilled) to water fill line.
5. Fit the cap onto comparator, making sure it is seated properly and caps tightly. Shake thoroughly.
6. Allow soil to settle and color to develop for about a minute.
7. Compare color of solution against pH chart. For best results allow daylight (not direct sunlight) to illuminate the solution. Refer to the information that follows for adjusting soil pH, if required, as well as the pH Preference List enclosed.

NITROGEN, PHOSPHORUS & POTASH TESTS:

1. Fill a clean container with 1 cup of soil and 5 cups of water. (Larger or smaller quantities may be tested as long as the 1 part soil to 5 parts water proportions are maintained.) For best results use bottled or distilled water.
2. Thoroughly shake or stir the soil and water together for at least one minute; then allow the mixture to stand undisturbed until it settles (30 minutes to 24 hours, dependent on soil). A fine clay soil will take much longer to settle out than a coarse sandy soil. The clarity of the solution will also vary, the clearer the better, however cloudiness will not affect the accuracy of the test.
3. Select the appropriate comparator for the test you wish to make. Remove the cap and take out the capsules which should be the same color as the cap. Make sure the color chart (film) is in place. Do not interchange color charts between comparators.

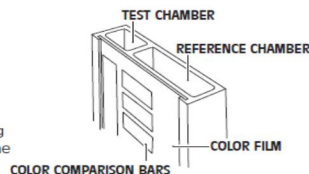
ADJUSTING SOIL pH - HOW MUCH TO APPLY

Material	pH Change	Sandy	Loamy	Clay
Dolomitic or calcic limestone	+0.5 unit (0.5 pH)	2.5	5.0	5.5
	+1.0 unit (1.0 pH)	5.0	8.5	11.0
Hydrated Lime	+0.5 unit (0.5 pH)	1.5 - 2.0	3 - 4	4.0 - 4.5
	+1.0 unit (1.0 pH)	3.5 - 4.0	6.0 - 6.5	8.0 - 8.5
Iron Sulfate	-0.5 unit (0.5 pH)	0.75	1.5	2.0
	-1.0 unit (1.0 pH)	1.5	3.0	4.0
Aluminum Sulfate	-0.5 unit (0.5 pH)	0.5 - 0.75	1 - 1.25	1.5
	-1.0 unit (1.0 pH)	1 - 1.25	2.25	3.0

Amounts listed are pounds per 100 square feet. Do not add more than 5lbs. of lime or sulfur in one application.

Green = pH
Purple = Nitrogen
Blue = Phosphorus
Orange = Potash

A dropper is provided to facilitate transferring the test solution into the color comparator.



4. Using the dropper provided, fill the test and reference chambers to the fill mark on the chart with solution from your soil sample. Solution is added to the reference chamber to compensate for any discoloration in the tested sample caused by the soil. Avoid disturbing the sediment. Transfer only liquid.
5. Remove one of the appropriate colored capsules from its poly bag. Holding the capsule horizontally over the test chamber, carefully separate the two halves and pour the powder into the test chamber.
6. Fit the cap on the comparator, making sure it is seated properly and caps tightly. Shake thoroughly.
7. Allow color to develop for 10 minutes. Do not allow the color to develop for more than 10 minutes.
8. If flakes of blue color appear to have settled to the bottom of the phosphorus color comparator during the 10 minute development period, shake the comparator to suspend them in the solution.
9. Compare the color of the solution in the test chamber to the color chart. For best results, allow daylight (not direct sunlight) to illuminate the solution in both the test and reference chambers. Judge colors, if necessary, and note your results for future reference. Follow the same easy steps for each of the N, P & K tests. When you have the test results you need, refer to the information below.

TO RAISE OR LOWER pH OF YOUR SOIL

Raising and lowering pH is not an exact science & most plants have a reasonably wide tolerance, certainly to within 1 pH point. Consult the enclosed pH Preference List and you will see that the majority can manage well on a pH around 6.5 but some need an alkaline soil and some a particularly acid soil. Altering pH takes time so do not expect rapid changes; rather, work steadily towards giving a plant its ideal conditions.

ADJUSTING pH

pH can be adjusted to provide more suitable growing conditions for the different plants you wish to grow. Or, you can leave the pH of the soil as it is and select plants that like the level revealed by your test. Once you have your pH reading, check the enclosed pH Preference List for the pH levels of over 450 popular plants, trees, shrubs, vegetables and fruits. If your pH reading differs significantly from the list's recommended levels, follow instructions below for adjusting soil pH. You can correct pH at any time of the year but it is best to start in the Fall and check progress in the Spring. After working to adjust your soil, retest for pH level in 40-60 days. If results are still significantly off, retreat your soil, not exceeding recommended application levels. Allow one month to pass between adding lime and adding fertilizers.

SOIL TYPES:

Sandy Soils: A light, coarse soil comprised of crumbling and alluvial debris. **Loam Soils:** A medium friable soil, consisting of a blend of coarse (sand) alluvium and fine (clay) particles mixed within fairly broad limits with a little lime and humus. **Clay Soils:** A heavy, clinging, impermeable soil, comprised of very fine particles with little lime and humus and tending to be waterlogged in winter and very dry in summer.

FERTILIZER RECOMMENDATIONS

FEEDING PRIOR TO PLANTING

Adequate reserves of plant food should be available in the soil before planting vegetables, preparing a seed or flower bed, sodding or seeding a lawn, or planting shrubs and trees. To make up any deficiencies, apply fertilizers from the following chart according to your soil test result.

TEST RESULTS	(0) Depleted	(1) Deficient	(2) Adequate	(3&4) Surplus / Sufficient
Nitrogen Fertilizers (%N)				
Dried Blood (11%)	36	19	6	N/A
Nitrate of Soda (16%)	27	14	3	N/A
Phosphate Fertilizers (%P)				
Bone Meal (19%)	27	14	6	N/A
Triple Superphosphate (46%)	10.25	5.25-5.5	2.25	N/A
Potash Fertilizers (%K)				
Muriate of Potash (60%)	8.75 - 9	4.75-5	2.25-2.5	N/A

Amounts listed are ounces per 100 square feet. (Ounces referred to are by weight)

FEEDING ESTABLISHED PLANTS AND BEDS

Based on your test results, apply the appropriate fertilizer(s) in the amounts recommended in the following chart.

RECOMMENDATIONS FOR N, P AND K RESULTS

	(0) Depleted			(1) Deficient			(2) Adequate			(3&4) Surplus / Sufficient
	N	P	K	N	P	K	N	P	K	
Lawn	22.0-22.5	0.75-1.0	4.75-5.0	14.0-14.5	1.0-1.5	2.25-2.5	3.75-4.0	0	0	N/A
Fruit	14.0-14.5	6.5	13.5-14.0	7.75-8.0	4.0-4.25	8.75-9.0	3.75-4.0	2.25	4.75-5.0	N/A
Flower	14.0-14.25	6.5	13.5-14.0	7.75-8.0	4.0-4.25	8.75-9.0	3.75-4.0	2.25	4.75-5.0	N/A
Shrubs (flowering)	14.0-14.25	8.25-8.5	13.5-14.0	7.75-8.0	4.0-4.25	8.75-9.0	3.75-4.0	1.0-1.25	4.75-5.0	N/A
Shrubs (foliage)	22.0-22.5	10.5-10.75	8.75-9.0	14.0-14.5	5.25-5.5	4.75-5.0	3.75-4.0	2.25	2.25-2.5	N/A
Veggies (root)	14.0-14.25	12.0-12.25	8.75-9.0	14.0-14.5	5.25-5.5	4.75-5.0	3.75-4.0	3.0	2.25-2.5	N/A
Veggies (leafy)	28.25-29.0	10.25	8.75-9.0	14.0-14.5	5.25-5.5	4.75-5.0	7.75-8.0	2.25	2.25-2.5	N/A
Tree	14.0-14.5	10.25	8.75-9.0	7.75-8.0	5.25-5.5	4.75-5.0	3.75-4.0	2.25	2.25-2.5	N/A
General Feed	22.0-22.5	8.25-8.5	8.75-9.0	10.5-11.0	4.0-4.25	4.75-5.0	3.75-4.0	1.0-1.25	2.25-2.5	N/A

The recommendations are based on the following fertilizers sources: Nitrate of Soda (16% N), Triple Superphosphate (46% P₂O₅) and Muriate of Potash (60% K₂O). The amounts listed are in oz. / 100 sq. ft. (Ounces referred to are by weight, not volume.) If you wish to use other fertilizer, simply check the package for the percentage of nutrients for N, P, & K and adjust the application level accordingly.

SPECIAL RECOMMENDATIONS FOR LAWNS

For a new lawn, pay special attention to soil preparation before planting. Proper soil preparation for any size lawn will have a significant impact on the amount of water and care it demands in the future. Till the soil to a depth of at least 12" and incorporate plenty of organic material (9" or more). Test your soil for pH and adjust to the levels recommended on the pH Preference List for your type of grass. Refer to the previous chart for recommended lime or sulfate applications.

For established lawns, Nitrogen is the most essential nutrient to promote lush growth and deep, green color. Phosphorus and Potash, in lesser quantities, are also important for strong root formation and growth. Compound fertilizers will supply all 3 nutrients, or you can select an individual fertilizer, such as Nitrate of Soda. The following chart gives recommended application levels specifically for lawns, based on your Nitrogen soil test results.

Fertilizer Type	(0) Depleted	(1) Deficient	(2) Adequate	(3&4) Surplus / Sufficient
24 - 4 - 4	4.0 lbs.	2.0 lbs.	1.0 lb.	N/A
24 - 3 - 4	3.1 lbs	1.55 lbs	.77 lbs	N/A
30 - 4 - 4	3.0 lbs	1.5 lbs	.75 lbs	N/A

Amounts listed are pounds per 1000 square feet

SAFETY & HYGIENE

Dispose of test solutions by rinsing down the sink. Empty gelatin capsules should be disposed of immediately with household waste. Remove the color charts. Wash the comparators and caps in warm, soapy water immediately after each use. Make sure any sediment or color staining is removed. Rinse well and dry.

Replace the color charts on the appropriate comparators. Each bag of capsules should be stored inside its comparator. Fit the caps on each comparator. Place all components back into the package. The blister pack has been specially designed to be reused as a storage container.

Store your kit in clean, dry conditions, indoors. The powders are safe in normal domestic terms but like all chemicals & pharmaceuticals, they should be put away and kept out of reach of children.

Try to avoid touching the powders. Always wash your hands thoroughly after making your tests. Do not eat, drink or smoke while using the soil test kit. Keep powders away from food, drink and animal feed. If taken internally, drink copious amounts of water and seek medical advice.

CAUTIONS

Where a lot of fertilizer is needed to correct one plant food, divide the applications over several weeks. Do not add lime and fertilizer together; lime first. Allow at least one month to pass before applying fertilizer. Retest 30 days after applying fertilizer.

Luster Leaf Products, Inc.
2220 Techcourt Woodstock, Illinois 60098
www.lusterleaf.com

APPENDIX E: Water Quality Quiz

Name: _____ Natural Resources Score: _____ out of 12

Date: _____ Water Quality Quiz

Select the best possible answer to these questions based on the information covered so far in this unit of study.

1. To be considered conservation tillage, around _____ % of the previous crops residue needs to be left on the soil surface.
 - a. 10
 - b. 20
 - c. 30
 - d. 40
2. Which two nutrients are most likely to contribute to water quality issues in a lake or pond?
 - a. Potassium and calcium
 - b. Magnesium and iron
 - c. Nitrogen and phosphorus
 - d. Boron and iron
3. How can wetlands benefit the health of a watershed?
 - a. Reduce erosion
 - b. Help filter water
 - c. Lead to increased groundwater recharge
 - d. All of the above

- e. None of the above
4. Runoff amounts are greatest from areas featuring a lot of _____ surfaces.
 - a. Grassy
 - b. Flat
 - c. Impervious
 - d. Dark
 5. True or False: If a little lawn fertilizer helps make your lawn green, it's best to use as much as possible to make it look even better.
 6. True or False: Water that flows into a storm sewer is almost never treated before reaching a stream, creek, river, or lake.
 7. What is a watershed divide?
 - 8-10. List three things farmers can do to reduce erosion and runoff issues from their land.
 - 11-12. Compare point source pollution to nonpoint source pollution.

APPENDIX F: Slides for PowerPoint Review Game

Main game slide with point values and categories, played as a Jeopardy-style game.

Farm-Related Water Issues	Non-Farm Water Issues	Water Pollution	Watersheds	A Cool Glass Of Random Water ?s
100	100	100	100	100
200	200	200	200	200
300	300	300	300	300
400	400	400	400	400
500	500	500	500	500

The following slides feature the questions and answers for the review game. A hyperlink is in place to return to the main game screen after each answer question slide is used.

Farm-Related Water Issues 100

What is the greatest use of water in farming in the USA today?

Farm-Related Water Issues 100

Irrigation

Farm-Related Water Issues 200

What technology allows farmers to be more efficient and environmentally-friendly with fertilizer application?

Farm-Related Water Issues 200

Precision agriculture. It allows farmers to know exactly where nutrients are and are not needed in a field.

Farm-Related Water Issues 300

Manure _____ systems greatly reduce potential runoff from fields and reduce odor.

Farm-Related Water Issues 300

Injection

Rather than spreading manure on the surface, injection reduces odor and runoff.

Farm-Related Water Issues 400

In an effort to clean waterways, _____ strips of permanent vegetation should be maintained along ditches and streams.

Farm-Related Water Issues 400

Buffer Strips

Also, grass waterways in fields greatly reduce water quality issues from fields.

Farm-Related Water Issues 500

How can reduced tillage help improve water quality?

Farm-Related Water Issues 500

The more residue on the surface of the soil, the less erosion and runoff from that soil into nearby waterways. If rain hits bare soil it can erode more than if it hits plant material from the previous crop.

Non-Farm Water Issues 100

How can excessive use of road salt impact water quality?

Non-Farm Water Issues 100

Excessive road salt contributes sodium chloride to aquatic ecosystems, which is hard on fish and it can drinking water quality.

Non-Farm Water Issues 200

How can a parking lot impact a fish in a nearby lake?

Non-Farm Water Issues 200

Water that is runoff from a parking lot flows through storm sewers to nearby waters untreated, possibly contaminating a river or lake's ecosystem.

Non-Farm Water Issues 300

Most streets, parking lots, roofs, and sidewalks are examples of _____ surfaces.

Non-Farm Water Issues 300

Impervious surfaces – they don't allow water to soak in

Non-Farm Water Issues 400

How is lawn fertilizer a potential culprit of water quality issues?

Non-Farm Water Issues 400

Some people apply excessive fertilizer, or accidentally spread it on sidewalks and streets. It flows to nearby waters when it rains.

Non-Farm Water Issues 500

This macronutrient is no longer found in some lawn fertilizers due to its connection to potentially toxic algae blooms in lakes and oceans.

Non-Farm Water Issues 500

Phosphorus.

Along with nitrogen, phosphates are major contributors to water quality issues in lakes.

Water Pollution 100

Pollution coming from an obvious source is what type of pollution?

Water Pollution 100

Point Source Pollution

Water Pollution 200

Pollution coming from sources that are unidentifiable or from numerous sources is called what?

Water Pollution 200

Nonpoint Sources

Water Pollution 300

Excessive nutrients in a pond or lake eventually leading to low dissolved oxygen levels results in a condition called...

Water Pollution 300

Eutrophication

Water Pollution 400

Explain two things that can be done to help a pond or lake with very low dissolved oxygen levels?

Water Pollution 400

Reduce the nutrient load by addressing runoff issues in the watershed, increase buffers in the area, operate an aerator in the lake

Water Pollution 500

Excessive erosion in an area can lead to _____ in water bodies.

Water Pollution 500

Turbidity – suspended soil particles in water.

Can be measured with a secchi disk and also be caused by invasive carp that uproot plants and stir up sediment

Watersheds 100

What is a watershed?

Watersheds 100

To put it very simply, a watershed is an area that provides runoff for a stream or reservoir.

Watersheds 200

What is a watershed divide?

Watersheds 200

A watershed divide is a ridge or area of higher ground that forces water to drain towards or away from a watershed.

Watersheds 300

What effect does terrain have on a watershed?

Watersheds 300

Terrain, referring to topography, is an important feature of a watershed. Steep terrain can lead to faster drainage and the possibility of increased soil erosion.

Watersheds 400

How can wetlands and bio-retention basins by parking lots help water quality within a watershed?

Watersheds 400

They capture water and filter it, allow it to soak into the ground to recharge groundwater and reduce flooding issues. They keep water from flowing directly to storm sewers and streams.

Watersheds 500

How can the health of Minnesota watersheds impact places across the country?

Watersheds 500

Water that flows within the Minnesota River, Mississippi River, and St. Croix River watersheds all eventually go downstream to the Gulf of Mexico. Some MN watersheds go to the Great Lakes or the Arctic. Excessive nutrients from runoff can impact many places downstream.

A Cool Glass Of Random Water ?s 100

How can cover crops help water quality in farmland areas?

A Cool Glass Of Random Water ?s 100

Cover crops can reduce erosion, break up soil compaction (especially with tillage radish), and keep soil nutrients in place

A Cool Glass
Of Random
Water ?s 200

What is strip tillage?

A Cool Glass
Of Random
Water ?s 200

A farming practice where strips of minimum tillage are spaced to match planting rows, fertilizer is put in the ground as needed, and minimum surface disturbance happens. Erosion and runoff is minimal.

A Cool Glass
Of Random
Water ?s 300

How can rainwater be managed in urban settings? Explain two possible options.

A Cool Glass
Of Random
Water ?s 300

Install porous concrete/paver systems, rain gardens, use rain barrels, or plant a green roof to reduce water flow to storm sewers.

A Cool Glass
Of Random
Water ?s 400

Why is groundwater contamination a greater concern in areas with sandy soils?

A Cool Glass
Of Random
Water ?s 400

Water moves more through sand than other soil types, bringing certain nutrients with it

A Cool Glass
Of Random
Water ?s 500

What is the Conservation Reserve Program and how can it help water quality?

A Cool Glass
Of Random
Water ?s 500

CRP is a program that takes land susceptible to erosion out of crop production in favor of native vegetation. It leads to reduced erosion and runoff, which is good for water quality.

APPENDIX G: Water Quality Unit Test

Name: _____ Date: _____ Score: ____ out of 50

Water Quality Unit Test

Select the best possible option for each question.

1. Solid material suspended in water indicates levels of
 - a. Fish in the water
 - b. Turbidity
 - c. Hardness
 - d. None of the above
2. Which two nutrients are most likely to lead to increased phytoplankton and eutrophic conditions in ponds and lakes?
 - a. Nitrogen and phosphorus
 - b. Nitrogen and potassium
 - c. Calcium and iron
 - d. Iron and nitrogen
3. Only ____ % of the water on earth is freshwater, and of that percentage, only ____ % is available for use.
 - a. 3, 1
 - b. 3, 50
 - c. 5, 4
 - d. 5, 1

4. Which of the following can contribute to lower dissolved oxygen levels in water?
 - a. Decomposing organic matter
 - b. Some algae and plant growth
 - c. Operation of an aerator
 - d. Cooler water temperatures
5. Home and business owners can set up _____ gardens on the properties to reduce storm water issues, beautify property, and provide for some wildlife species.
 - a. Rain
 - b. Vegetable
 - c. Organic
 - d. Rock
6. What can be done to help improve dissolved oxygen levels?
 - a. Aerate the water
 - b. Add chlorine
 - c. Test for water hardness
 - d. Add chlorides to the water
7. Which of the following is NOT an example of an impervious surface?
 - a. Sidewalk
 - b. Paved road
 - c. Mulch covered landscaping
 - d. Rooftop

8. Outlet pipes from a factory can be considered what type of pollution source?
 - a. Non-point source pollution
 - b. Point source pollution
 - c. Direct pollution
 - d. None of the above
9. What areas need to be most concerned with nitrates leaching into groundwater?
 - a. Places with clayey soils
 - b. Places with lots of farmland
 - c. Locations with sandy soils
 - d. Forest land regions
10. Most northern states use this mix on winter roads, leading to health issues in aquatic ecosystems.
 - a. Sodium chloride
 - b. Iron sodium
 - c. Phosphate chlorine
 - d. Sand
11. What types of plants are ideal for green roof systems?
 - a. Annual plants
 - b. Perennial plants
 - c. Legumes
 - d. Fruit trees

12. Manure _____ systems lead to less runoff from nutrients in manure from fields.
- a. Spraying
 - b. Injection
 - c. Consumption
 - d. Toxicity
13. What baseball stadium features systems to conserve water resources, using rainwater for irrigation and cleaning?
- a. Miller Park
 - b. Fenway Park
 - c. Wrigley Field
 - d. Target Field
14. What type of system reduces runoff from sidewalks, streets, and parking lot areas the most?
- a. Porous concrete
 - b. Gravel
 - c. Asphalt
 - d. Tar and rocks
15. What is the ideal pH for soil in fields and water for human consumption?
- a. Around 9
 - b. Around 4
 - c. Around 7
 - d. Around 10

16. Many precision agriculture systems use soil sampling and ____ technology to apply fertilizer and manure where needed.
- a. GPS
 - b. Genetic
 - c. Seed
 - d. None of the above
17. What do bio-retention areas near parking lots and roads and wetlands accomplish for water quality?
- a. Reduce flooding
 - b. Filter water
 - c. Allow water to recharge groundwater supplies
 - d. All of the above
 - e. None of the above
18. Conservation tillage systems leave at least ____ percent of the previous crop's residue on the surface of the soil.
- a. 10
 - b. 20
 - c. 30
 - d. 40

19. When can algae in lakes and ponds lead to reduced dissolved oxygen levels?
- a. When it is first developing
 - b. When the aerator is installed
 - c. When it is dead and decomposing
 - d. None of the above
20. Which tillage method does minimal surface disturbance, results in very little runoff, and puts fertilizers in the ground where plants can reach them when they develop?
- a. Mulch tillage
 - b. Strip tillage
 - c. Moldboard plowing
 - d. Chisel plowing
21. Which of the following leave soil exposed to the highest level of erosion and nutrient runoff?
- a. Mulch tillage
 - b. Strip tillage
 - c. Moldboard plowing
 - d. Chisel plowing
22. A bag of lawn fertilizer with a label reading 15-0-21 contains no
- a. Nitrogen
 - b. Phosphorus
 - c. Potassium
 - d. Zinc

23. What is the name of the program where land is taken out of crop production and farmers get payments for not farming it?
- a. Habitat Restoration Program
 - b. Conservation Reserve Program
 - c. Field Removal Program
 - d. Erosion Reduction Program
24. Which of the following can impact the health of a watershed?
- a. Land use in the watershed
 - b. Slope of the land in the watershed
 - c. Existence of impervious surfaces
 - d. All of the above
25. Which cover crop plant is ideal for reducing soil compaction, which allows water to soak into the ground more effectively?
- a. Annual ryegrass
 - b. Oats
 - c. Peas
 - d. Tillage radish

True or False Statements -

26. True or False: All water in Minnesota flows to the Gulf of Mexico through the Mississippi River.
27. True or False: A simple way to reduce storm water overload in an area is to install a rain barrel.

28. True or False: Most storm sewer drainage systems treat water before releasing it to streams.
29. True or False: Buffer strips and grass waterways play no role in water quality in farmland areas.
30. True or False: Even dog droppings from a lawn or street can lead to reduced water quality of lakes.
31. True or False: Very little water is used for irrigation in the USA.
32. True or False: Wetlands have no impact on groundwater recharge.
33. True or False: Green roof systems have the potential to reduce urban heat island situations.
34. True or False: Lake aerators actually inject oxygen into bodies of water.
35. True or False: It is pointless for people to take soil nutrient tests of lawns before fertilizing.
36. True or False: Cover crops do very little to keep nutrients in place in a field.

Short answer questions:

37-38. Why is nonpoint source pollution so much tougher to address than point source pollution?

39-40. Eliminating the use of fertilizers is likely not really an option for society in the 21st century. Why is that?

41-42. Identify the path of water from our town as it flows through a watershed and what rivers it flows to along its way to the sea.

43-44. What is a watershed divide? Explain the concept and illustrate if you wish.

45-46. What can be done to minimize the impact of nonpoint source pollution on water?

47-48. What is the proper procedure for collecting water samples for testing dissolved oxygen levels?

49-50. What will you do now and in the future to impact water quality in a positive way?